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PORTABLE COMPUTING SYSTEM FOR

USE IN TOXIC GAS EMERGENCIES

DISCLAIMER

This report has been prepared by the Air Resources Branch of the Ministry of the Environment on the basis of work performed internally, work by consultants, and published work in scientific literature. All reasonable care has been taken, but the Ministry cannot absolutely guarantee the accuracy or applicability to any given situation of this report or the computer programs described herein.

The Ministry of the Environment takes no responsibility whatsoever for any outcome resulting from use of this report or computer program.

SUMMARY

This report serves as the documentation for the Portable Computing System for Use in Toxic Gas Emergencies. This system, developed and maintained by the Special Studies and Research Management Unit of the Air Resources Branch, has three main objectives:

a) to provide hazardous contaminant and dispersion modelling information quickly in an emergency;

b) to be "user friendly" to all users; and

c) to be easily transportable so that it can be used at home or at emergency sites.

The report is written in modules so that readers of different sophistication in computer modelling of toxic gas dispersion can use different parts of it. Chapter 1 details the rationale for developing the system and the scope of its intended use. Chapter 2 provides some background information on the modelling calculations and the information sub-system. Chapter 3 is a user's manual, giving step-by-step instructions for use of the system. Chapter 4 contains flow charts showing the system design as well as the data structure of the files making up the information sub-system.

The programs and further documentation can be obtained from:

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880 Bay Street, 4th Floor
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PORTABLE COMPUTING SYSTEM FOR USE IN TOXIC GAS EMERGENCIES

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CHAPTER 1: INTRODUCTION

1. INTRODUCTION

The extensive use of hazardous gases in our industrial society results in significant storage, handling and transportation problems. Toxic gases such as ammonia, chlorine and hydrogen sulphide are stored in refrigerated vessels or pressurized tanks and are transported by ship, truck, and train.

The manufacturers and shippers of these materials do their best to ensure that the materials are stored and moved safely and that hazards due to toxic properties of these materials are minimized. Failure of various elements of these systems, however, can sometimes disrupt our lives. In Toronto and Mississauga, a train derailment in 1979 caused a quarter of a million people to be evacuated and police, firefighters, meteorologists, hospital staff, ambulance crews, and environmental scientists all played critical roles in handling the emergency. A train derailment at Medonte, near Barrie, Ontario, in 1982 threatened the surrounding community with the potential rupture of a tank car containing 39 tons of anhydrous hydrogen fluoride. In other countries lives have been lost in such accidents.

In 1980, the Ontario Ministry of the Environment began development of computerized dispersion models on an IBM mainframe computer to estimate the concentration of toxic gases resulting from unusual releases to the atmosphere. The models can be used to help in decision-making about evacuation in the general area of an accident. When major emergencies occur outside usual business hours (as often happens), these programs can be run on a terminal from the home of MOE staff via telephone line. Since the user requires his phone line to run these models, however, his communication line is cut off. As well, if the mainframe is down for maintenance or for some other reason, these models cannot be used.

To avoid such situations, the Ministry of the Environment has adapted the Simple Gas Model and the Heavy Gas Model to a portable computer (IBM PC). The resulting system also contains useful information on

certain priority chemicals which might be involved in emergencies in Ontario. A portable computer can be brought to the emergency site and used there. If kept in the homes of personnel on a rota basis, it can also be used to provide a fast information response when major emergencies occur outside normal office hours.

This Portable Computing System for Use in Toxic Gas Emergencies (henceforth referred to as the GAS SYSTEM) is designed to be very user-friendly so that a minimum of computer competency is required to run it. It is not meant to replace the more sophisticated mainframe models. Rather, its main purpose is to provide fast, first-cut information to advise appropriate emergency handling authorities at the emergency site. The system will provide hazardous contaminants information, calculate toxic gas concentrations at different distances downwind of an emergency site, and display this information graphically against important marker levels such as TLV, STEL and IDLH values (Threshold Limit Values; Short Term Exposure Limits; Immediately Dangerous to Life or Health). This information will aid authorities in decision making about evacuation of people in the general area of the emergency. Meanwhile, professional modellers from industry and government can set up more detailed models for the particular circumstances.

CHAPTER 2: BACKGROUND

2.1 FORMATION OF HAZARDOUS VAPOUR CLOUDS

The accidental escape of chemicals during manufacture, storage, and transportation can harm the public. The understanding of the atmospheric dispersion of toxic vapours is, therefore, an essential element in chemical safety plans. One of the most important properties of such vapours is that many of them are denser than air. Many other vapours, although not normally denser than air, may become so under typical emergency conditions. Following are some examples of denser-than-air behaviour for gases that, at first sight, should be buoyant. This is important because such gases will tend to remain near the ground while moving downwind, thus increasing the risk in the downwind area.

Gases can be intrinsically dense because their molecular weight exceeds that of air. Chlorine is an example of a dense toxic vapour. The petrochemical industry produces and transports a range of flammable dense hydrocarbons such as propane, butane, and propylene. Although methane is a gas whose molecular weight is less than that of air, it is dense if released at its boiling point of -161°C. Natural gas is often stored or transported as liquid and a cold, dense vapour can be generated if liquified natural gas should be spilled onto land or water.

A superficially surprising example of a gas that can form a denser than air mixture is ammonia, which is chemically toxic. Its molecular weight is only 17 and, at its boiling point of -33°C, the vapour is less dense than air at 20°C. Nonetheless, there are several examples of accidental releases of ammonia from pressurized containers in which the resulting gas cloud was denser than air (Kaiser and Walker, 1978), or at least non-buoyant. The reason for this is as follows. If ammonia is kept as a liquid at the ambient temperature, it is under considerable pressure. If the vessel containing the ammonia should fail, there is an immediate bulk boiling of the liquid. About twenty per cent of its mass can typically vaporize, with the heat supplied by cooling the remaining ammonia to its boiling point. The vigour of the bulk boiling process can throw most, if not all, of the remaining liquid into the

air as a fine aerosol. At the same time, air is entrained. This air supplies heat to evaporate the ammonia droplets so that a mixture of air and ammonia, possibly at the boiling point of ammonia, is formed. Such a mixture can be denser than the surrounding air, if the circumstances favour the release of a substantial percentage of the ammonia as fine liquid droplets. Such a case occurred in the USA in May, 1976. Nineteen tons of anhydrous ammonia were released in a dense cloud in surburban Houston when a tanker truck crashed through a barrier on an elevated expressway.

Another example is hydrogen fluoride, a toxic gas used by the nuclear industry during the fuel manufacturing process, and by the chemical industry as a catalyst in alkylation plants. Its molecular weight is normally 20, but as a pure vapour it is highly associated and consists of a mixture of a hexamer and monomer with an effective molecular weight of about 70. Disassociation takes place as the hydrogen fluoride is diluted with air, but the heat required to do this is extracted from the mixture and tends to keep it denser than the surrounding air. However, there is no known example of a large scale accidental release in which this density effect has been observed.

From the foregoing examples, it is apparent that a knowledge of the way in which "heavy" toxic vapours disperse in the atmosphere is essential to analyse the potential risk in accidents involving toxic chemicals.

2.2 DISPERSION MODELS

After the release of a toxic vapour, its concentration at different distances downwind can be estimated using dispersion models. The purpose of the dispersion calculations presented in this portable computing system is to obtain a rough estimate of the dispersion of hazardous vapour. Various simplifying assumptions are incorporated into models of different sophistication. The reader should be aware of the inherent assumptions and the limits of applicability of these models. Otherwise, gross misinterpretation of the implications of a particular situation may result. For instance, the terrain is assumed

to be flat. In a real situation, channelling due to buildings or valleys can lead to higher concentrations than predicted.

The accidents dealt with can be subdivided into two major types:

a) Continuous Release (Plume Formation) - A leak occurs in a gas container or above the liquid level in a liquid container. Alternatively, liquid is released, forms a pool and evaporation causes vapour release to the atmosphere.

b) Instantaneous Release (Puff Formation) - This is the release of a large amount of gas in a very short time (in the order of seconds to minutes). A major rupture in a container of a highly volatile chemical can cause such a release, e.g. a BLEVE (Boiling Liquid Expanding Vapour Explosion).

Two types of dispersion model have been incorporated in the present system. The Simple Gas Model can deal with either a continuous or instantaneous release and uses different equations to estimate the concentration downwind for these two situations. The Heavy Gas Model, although a more mathematically sophisticated model, can only deal with instantaneous releases in our system. It will give a more realistic representation of an instantaneous heavy gas release.

2.3 SOURCE STRENGTHS

The use of these models requires that the amount of gas released (i.e. source strength) be known. Source strengths can be estimated using basic principles of thermodynamics and fluid mechanics. In the development of the following formulae, gases are assumed to behave ideally and the venting process is assumed to be isothermal. Equilibrium thermodynamics, although not strictly applicable, is employed for simplicity. These assumptions may not be valid in many cases, but they do give a worst-case scenario.

2.3.1 Gas Release

Gas will be released when the hole in the tank is above the liquid level. The maximum limiting flow rate for gas release is during "choked" flow. This flow rate is

$$q_v = C_d A P \sqrt{\left(\frac{KM}{RT}\right)\left(\frac{2}{K+1}\right)^{\frac{K+1}{K-1}}}$$

where q_v = vapour venting rate
T = absolute temperature in the tank
M = molecular weight
R = universal gas constant
P = tank pressure
K = specific heat ratio for the vapour
C_d = coefficient of discharge
A = area of rupture

The criterion for choked flow is

$$\frac{P}{P_a} > \left(\frac{K+1}{2}\right)^{\frac{K}{K-1}}$$

where P_a = atmospheric pressure.

For unchoked flow,

$$\frac{P}{P_a} \leq \left(\frac{K+1}{2}\right)^{\frac{K}{K-1}}$$

and the flow rate becomes

$$q_v = C_d A \sqrt{2P\rho_v \left(\frac{K}{K-1}\right)\left\{\left(\frac{P_a}{P}\right)^{\frac{2}{K}} - \left(\frac{P_a}{P}\right)^{\frac{K+1}{K}}\right\}}$$

where ρ_v = density of vapour.

2.3.2 Liquid Release

Liquid is released when the hole in the tank is below the liquid level. Then,

$$q_\ell = C_d A \rho_\ell \sqrt{2gH + \frac{2(P-P_a)}{\rho_\ell}}$$

where q_ℓ = instantaneous liquid venting rate
H = height of liquid column above hole
P = tank pressure
A = area of rupture
C_d = coefficient of discharge
ρ_ℓ = density of liquid
g = acceleration due to gravity
P_a = atmospheric pressure

Stiver and MacKay (1982) give the evaporation rate for chemicals that form a liquid pool when spilled on a ground or water surface as:

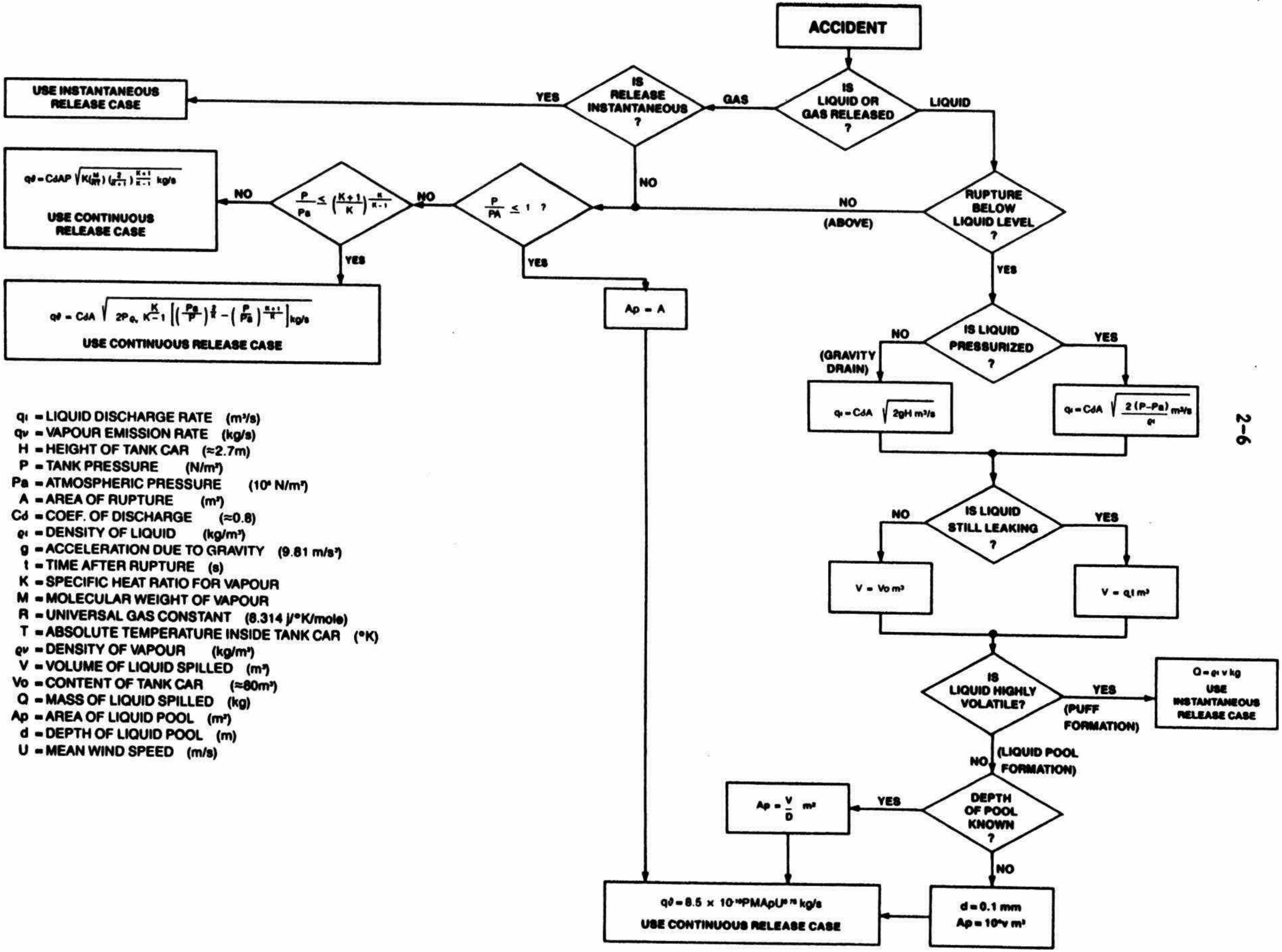
$$Q = \frac{K_m A_p PM}{RT}$$

where Q = evaporation rate (vapour release rate), kg/s
K_m = mass transfer coefficient, m/s
A_p = pool area, m^2
P = vapour pressure, Pascal (i.e. N/m^2)
M = molecular weight
R = gas constant, 8.314 (Pa)(m^3)/(mole)(°K)
T = temperature, °K

At a temperature of 20°C, the evaporation rate can be given numerically as

$$Q = 8.5 \times 10^{-10} A_p P M u^{0.78} \text{ kg/s}$$

where u = the wind speed in m/s.



q_l = LIQUID DISCHARGE RATE (m³/s)
q_v = VAPOUR EMISSION RATE (kg/s)
H = HEIGHT OF TANK CAR (≈2.7m)
P = TANK PRESSURE (N/m²)
Pa = ATMOSPHERIC PRESSURE (10^5 N/m²)
A = AREA OF RUPTURE (m²)
C_d = COEF. OF DISCHARGE (≈0.8)
ρ_l = DENSITY OF LIQUID (kg/m³)
g = ACCELERATION DUE TO GRAVITY (9.81 m/s²)
t = TIME AFTER RUPTURE (s)
K = SPECIFIC HEAT RATIO FOR VAPOUR
M = MOLECULAR WEIGHT OF VAPOUR
R = UNIVERSAL GAS CONSTANT (8.314 J/°K/mole)
T = ABSOLUTE TEMPERATURE INSIDE TANK CAR (°K)
ρ_v = DENSITY OF VAPOUR (kg/m³)
V = VOLUME OF LIQUID SPILLED (m³)
Vo = CONTENT OF TANK CAR (≈80m³)
Q = MASS OF LIQUID SPILLED (kg)
Ap = AREA OF LIQUID POOL (m²)
d = DEPTH OF LIQUID POOL (m)
U = MEAN WIND SPEED (m/s)

The evaporation rates at temperatures other than 20°C use the following equation:

$$Q_t = Q_{20°C} \times \frac{P_t}{P_{20°C}} \times \frac{T_{20°C}}{T_t}$$

where the subscript t denotes the temperature at which the evaporation rate is desired.

The accompanying flow chart shows how the computer program determines the release rate of toxic gases in an accident.

2.4 SIMPLE GAS MODEL

This model is essentially a simplified mathematical description of the physical behaviour of the released gas. In its simplest form, the model expresses the mass balance of the released gas.

In using the puff and plume equations described below, the following assumptions have to be noted (from TIPS Manual, Environment Canada):

a) The vapour that is diffusing is neutrally buoyant; that is, there is no gross movement of the vapour cloud caused by either gravity or buoyancy.

b) Mixing with air is uniform throughout the vapour cloud.

c) The concentration obtained is time-averaged.

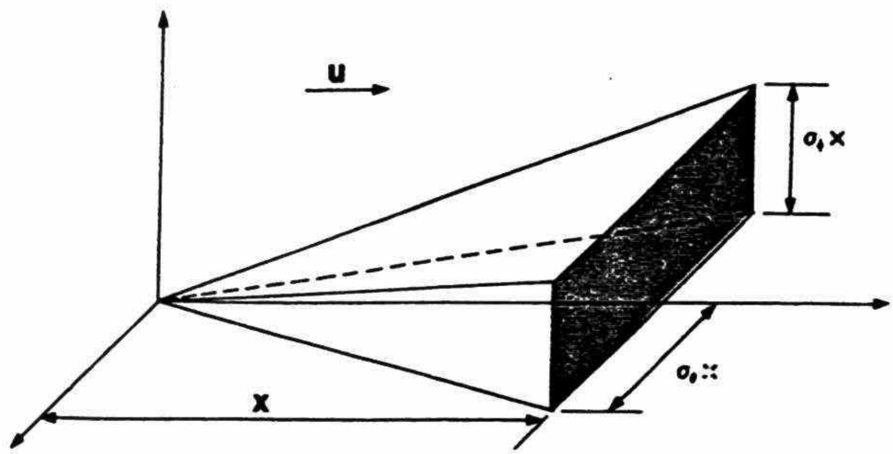
d) The wind is uniform throughout the vertical extent of the cloud.

e) The terrain is assumed flat (i.e. no terrain effects).

f) No depletion of the puff/plume (e.g. by deposition).

2.4.1 Continuous Release Case (Plume), Simple Gas Model

Consider a continuous release of gas at a rate of Q at ground level. Plume behaviour can be simplified as a half-pyramid with the apex at the source. Figure 1 illustrates this.



u : MEAN WIND SPEED
x : DOWN WIND DISTANCE FROM THE SOURCE
σ_ϕ : VERTICAL FLUCTUATION
σ_θ : HORIZONTAL FLUCTUATION

FIGURE 1

If we consider the shaded cross-section, the conservation of matter can be stated as

$$Q = 2\sigma_\theta x \sigma_\phi x u C \tag{1}$$

where C is the concentration of the gas at distance x. Formula (1) can be rewritten as

$$C = \frac{Q}{2\sigma_\theta x \sigma_\phi x u} \tag{2}$$

We can see that:

(a) the concentration is directly proportional to the emission rate Q;

(b) the concentration is inversely proportional to the wind speed u; and

(c) the concentration falls approximately as x^2.

The height of the plume in the atmosphere cannot exceed the mixing layer height, z. When the plume height reaches z, the plume will spread horizontally only, instead of both horizontally and vertically as shown in Figure 2.

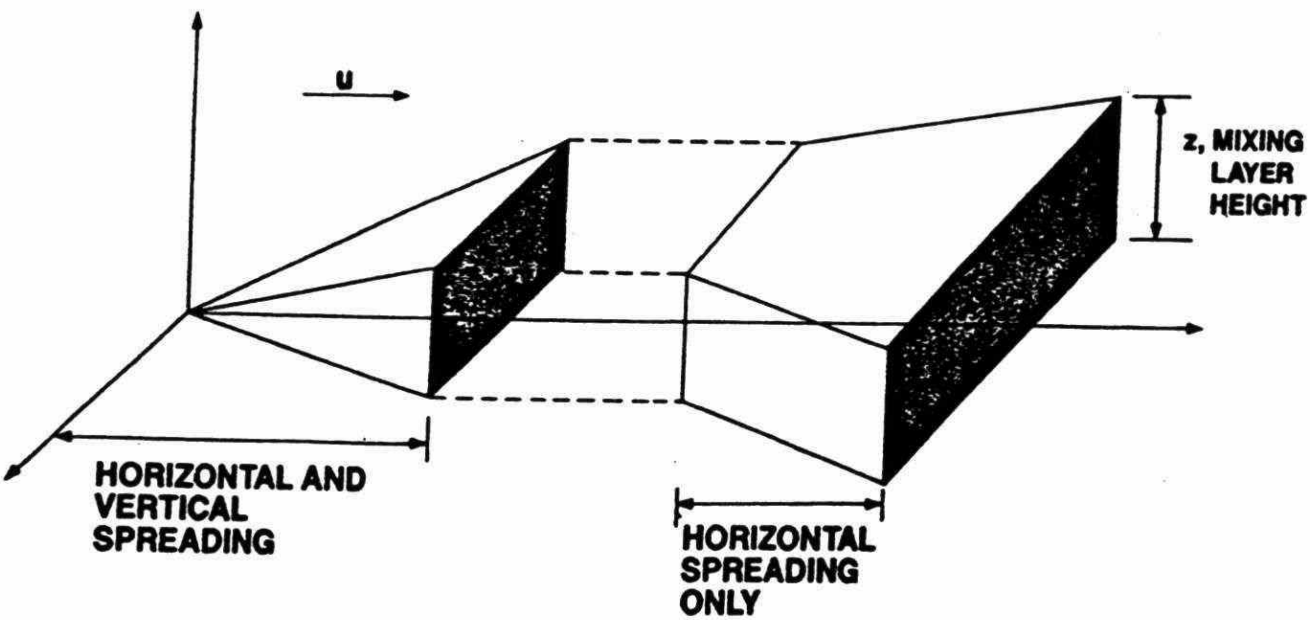


FIGURE 2

Equation (2) now becomes

$$C = \frac{Q}{2\sigma_\theta\, x\, \sigma_\phi x u}, \quad z < \sigma_\phi x \qquad (3a)$$

$$C = \frac{Q}{2\sigma_\theta x z u}, \quad z \geq \sigma_\phi x \qquad (3b)$$

Using equations (3a) and (3b), the maximum permissible emission rate or

a caution distance can be calculated, provided that the critical concentration is known.

2.4.2 Instantaneous Release Case (Puff), Simple Gas Model

In the simple gas model, instantaneous release is considered as a puff release. That is, all the material released is assumed to be contained within an ellipsoidal puff (Fig. 3) and the distribution of the toxic gas within the puff is assumed to be Gaussian. Parameters 'a', 'b' and 'c' define the major and minor axes of the puff. As the puff moves downwind, it increases in size. Equation 4 gives the new value of the major and minor axes of the puff as it moves downwind.

Equation 4a gives the concentration within the puff.

Since the material in the puff cannot escape the capping inversion, when the vertical axis 'c' of the puff exceeds the mixed layer height, it is set equal to this height; i.e., c = z. Equation 4b then gives the concentration within the puff.

Then conservation of mass requires that

$$C = \frac{2W}{(2\pi)^{3/2}(\sigma_\theta x)^2 \sigma_\phi x}, \quad \sigma_\phi x < z \tag{4a}$$

$$C = \frac{2W}{(2\pi)^{3/2}(\sigma_\theta x)^2 z}, \quad \sigma_\phi x \geq z \tag{4b}$$

where C is the concentration of the gas at the centre of the puff and z is the mixing layer height.

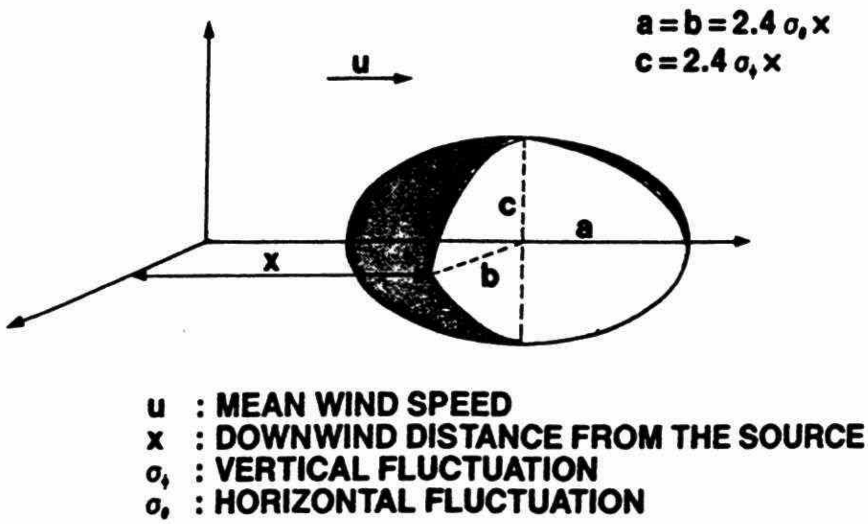


FIGURE 3

The time of exposure to the puff at a distance x downwind from the source is the time taken for the ellipsoid to pass that point.

$$\text{Time of exposure} = \frac{8\sigma_\theta x}{u} \tag{5}$$

If a critical concentration is given, equations (4a) and (4b) can be reversed to calculate a caution distance.

2.5 HEAVY GAS MODEL

In the present system, the heavy gas model can only be used for instantaneous releases. In some cases the hazardous gas is released in a very short time interval (i.e. practically instantaneous). Chlorine escaping suddenly from a fractured pressured vessel is a typical example. The gas appears in the form of a cloud which drifts downwind as it disperses. Figure 4 shows a schematic of a dispersing puff.

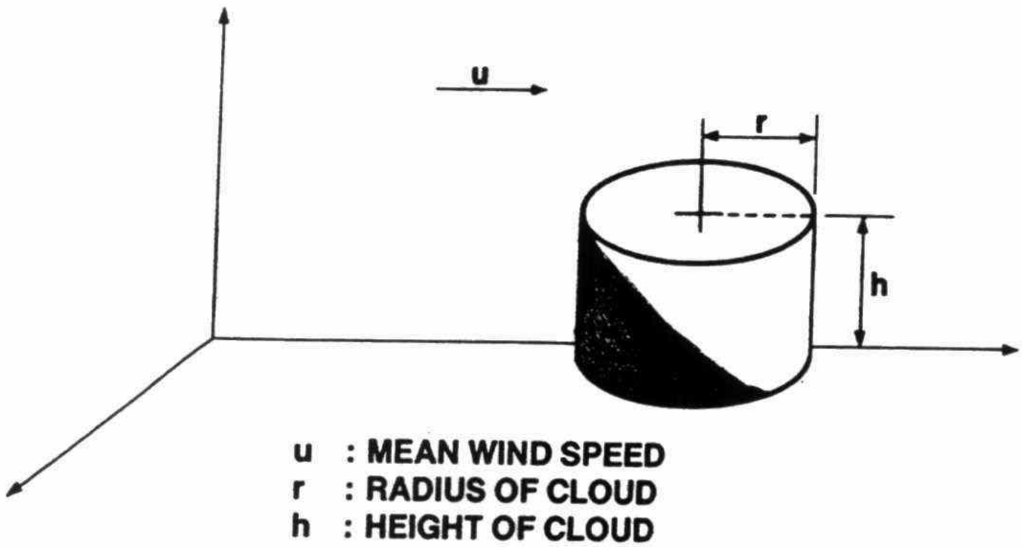


FIGURE 4

2.5.1 Cloud Formation

The fraction, δ, of the liquid mass thrown into the air-gas mixture as droplets during the release, evaporates. Depending upon the type of gas and release, this fraction may vary from almost zero to close to one. A typical value is 0.8 (Kaiser and Walker, 1978). The temperature of the cloud will not rise much until enough warm air has been entrained to evaporate the droplets. The necessary amount of entrained air is

$$M_{ad} = \frac{\delta M_g L_g}{C_{pa}(T_a - T_g) + L_w X_w} \qquad (6)$$

Here X_w is the mixing ratio of water vapour, L_w is the latent heat of evaporation or sublimation of water, M_g is the mass of the released gas, and L_g is the latent heat of the gas (K.J. Eidsvik, 1979). C_{pa} is the heat capacity (1005.7 J/kg) of air, which will be cooled during the evaporation process from ambient temperature T_a to T_g, usually the boiling point of the gas.

Ontario Ministry of the Environment, Air Resources Branch

INSTRUCTIONS FOR INSTALLING AND RUNNING EMERGENCY RESPONSE PROGRAM, MAY 1990 VERSION

INTRODUCTION:

The Emergency Response Program (**ERP**) resides on 3 installation diskettes. Please follow the steps listed below carefully.

If you are attempting to install **ERP** on a hard disk that already contains a previous version of **ERP**, delete the previous version prior to installation (i.e. delete the files and subdirectories in **C:\ERP**). Prior to deleting these files, back up any output files on **C:\ERP** that you may have produced while running the previous version of **ERP**.

If a mistake is made during installation, delete the files and subdirectories in **C:\ERP** and start over.

SYSTEM REQUIREMENTS:

One 5.25" Floppy Disk Drive as Drive A (360K or 1.2 megabytes)
One Hard Disk Drive (minimum 10 megabytes)
IBM XT/AT/386/486 or compatible system
DOS 2.0 or later version
Math coprocessor recommended, but not required

INSTALLATION:

The installation is performed on the C drive. Place Installation Diskette #1 in drive A and type:

A:\INSTALL

to begin the installation. Then follow the instructions as they appear. You will be prompted to insert the 3 diskettes in sequence.

RUNNING ERP:

After installation, you may run **ERP**. To run the program go to directory **C:\ERP** and execute the batch file **AUTOEXEC**. To do this, type:

C: , then
CD \ERP , then
AUTOEXEC

to run **ERP**.

The first module to be executed is **METINFO**. This module allows for the inputting of meteorology, source and receptor information. It should be noted that NOT ALL INFORMATION ASKED FOR IN THIS MODULE IS USED BY EVERY PROGRAM. For example, receptor and stack information is not used by the HEAVY GAS model. In addition, please note that the use of a unit emission rate (i.e. 1.0 grams/second) may be desired since this may make computations easier for multiple scenarios. To allow for the actual emission rate, simple multiply the final concentration by the actual emission rate. For example, if the final concentration at a given receptor is 1.22 ug/m**3 and the actual emission rate is 2 grams/second, multiply the two figures to get 2.44 ug/m**3. (For those concerned about unit conversions, note that using a unit emission rate implies that the units of concentration are actually (ug/m**3)/(g/s).)

SELECTING THE MODEL:

After the meteorology, source and receptor information is entered, a model menu is displayed (which you can enter directly from **METINFO** by typing **C**, for Continue). Enter the model which is to be run. The program will then branch to the chosen model and begin execution. There are some specific inputs required within the individual models. You will be prompted for any further information required by the model. Note that when a program is expecting input from the keyboard, you CANNOT terminate it. The only way to get out of the situation is by entering the required information or by rebooting (i.e. by simultaneously pressing the ALT, CNTL and DEL keys).

HEAVY and SIMPLE GAS MODELS:

To run the Heavy Gas or Simple Gas models, you must select a specific chemical from the chemical list. Follow the instructions as they appear on the screen. The Heavy Gas model contains two very important inputs: The **Amount of Gas Released** and the **Initial Radius of the Cloud**.

PROPOSED REGULATION 308 MODEL:

The Proposed Regulation 308 model requires as input meteorology, source and receptor data (inputted through **METINFO**, as described above). There are a variety of optional inputs that you may choose to enter. Each requires that a special code be used in place of a source parameter. These optional inputs and codes are summarized in the following table:

Optional Input Required	Code	Source Parameter to Use
Buoyancy Flux	-888	Stack Temperature
Momentum Flux	-888	Stack Exit Velocity
Initial Vertical Plume Height	-888	Building Height
Initial Horizontal Plume Width	-888	Building Width
Stack Temperature to Ambient	-999	Stack Temperature

If, for example, you wish to input you own buoyancy flux (as, for example, in a flare situation) then you must input **-888.0** for the stack temperature. This (clearly impossible) temperature is a code that indicates to the model that the buoyancy flux will be inputted by you, not calculated by the model. You will then be asked to enter the buoyancy flux when you run the model.

After the optional inputs have been entered, you will be asked for an output filename. If you wish the output to appear on the screen simply press **<enter>**. Otherwise, enter the filename. Please note that the filename should be a simple filename, with no path specified. If the file already exists, it will be overwritten. To view the file, exit **ERP** (i.e. go to **DOS**) and use the **TYPE** command. The file will be found in the directory **C:\ERP**.

SOURCE CODE:

Unlike some previous version of **ERP**, the source code is not automatically installed on the C drive. In order to retrieve the source code, place Installation Diskette #3 in Drive A and type:

A:\GETCODE

The source code will be automatically installed in **C:\ERP\SCODE**. Note that the source code must be decompressed, so installation will take a few minutes. Note that the BASIC programs are written in Microsoft QuickBASIC V4.5 and the FORTRAN programs are written in Microsoft FORTRAN V4.1. Batch files to aid in compilation and linking are included.

If you have any questions about installing or running **ERP**, please contact Mr. H. Sahota at 416-235-5764.

Since the mass of air entrained is assumed to be ten or twenty times that of the gas in the escaping puff, the law of conservation of momentum dictates that the initial velocity is roughly that of the surrounding air. The puff is assumed to move with the wind speed (measured at a height of 10 m).

2.5.2 Slumping

The initial spreading of the dense cloud resulting from a heavy gas release is controlled by gravitational effects. The cloud essentially slumps under the influence of gravity. To analyze this behaviour, we have followed Kaiser and Walker (1978) and assumed that the cloud is in the form of a cylinder with radius r and height h. The velocity of the edge of the cloud is adequately described by the liquid column analogy:

$$\frac{dr}{dt} = C\left[\frac{(\rho-\rho_a)}{\rho} gh\right]^{\frac{1}{2}} = \frac{C}{r}\left[\frac{(\rho-\rho_a)gV_o}{\pi\rho}\right]^{\frac{1}{2}} \tag{7}$$

where dr/dt is the spreading velocity of the cylinder of heavy gas, ρ is the density of the gas-air mixture in the cloud, ρ_a is the density of the surrounding air (1.2 kg/m^3 at 20°C), and C is a constant. Van Ulden (1974) suggested C = 1 as the constant with his field experimental results. We have also assumed that the volume and the concentration of the cloud remains approximately constant, at V_o and C_o respectively, as the cloud slumps. Integrating equation (7) gives

$$r^2 = r_o^2 + 2\left[\frac{(\rho-\rho_a)gV_o}{\pi\rho}\right]^{\frac{1}{2}} t \tag{8a}$$

$$\frac{dr}{dt} = \frac{1}{r}\left[\frac{(\rho-\rho_a)gV_o}{\pi\rho}\right]^{\frac{1}{2}} \tag{8b}$$

$$C_o = \frac{M_g}{V_o} \tag{8c}$$

Since the concentration remains essentially unchanged at its initial value throughout the slumping phase, exposure levels could be exceedingly high at distances of the order of a few kilometers from the release site.

2.5.3 Termination of Slumping

Slumping is terminated by entrainment of air. This results in a dense cloud which hugs the ground as it travels downwind while the height of the cloud begins to grow slowly. Sooner or later the cloud or dispersing gas must become so dilute that atmospheric turbulence becomes dominant in controlling cloud growth. Van Ulden (1974) recommends as a criterion for the end of the slumping phase setting the turbulence energy density equal to the mean potential energy density; that is to say

$$\tfrac{1}{2}\,(\rho-\rho_a)gh = 2\rho u_*^{\,2} \tag{9}$$

Here u_* is the friction velocity due to mechanical turbulence and is related to the mean wind speed u by $u_* = cu$, where c is a "surface drag constant" that depends on the weather category.

Applying equation (7), this criterion is equivalent to

$$\left[\frac{(\rho-\rho_a)gh}{\rho}\right]^{\frac{1}{2}} = \frac{dr}{dt} = 2u_* \tag{10}$$

Combining equations (8b) and (10), the radius at the end of the slumping phase can be shown to be

$$r_T = \frac{D}{2u_*} \quad \text{where } D = \left[\frac{(\rho-\rho_a)gV_o}{\pi\rho}\right]^{\frac{1}{2}} \tag{11}$$

Then the duration of the slumping phase is given by equation (8a) as

$$t_T = \frac{r_T^{\,2}-r_o^{\,2}}{2D} \tag{12}$$

After $t = t_T$, dr/dt becomes independent of r. To be consistent with equation (10), dr/dt = $2u_*$ and

$$r = r_T + 2u_*[t-t_T] \qquad (13)$$

Similarly, for the growth of cloud height, Eidsvik gives

$$h = h_T + \alpha u_*[t-t_T] \qquad \text{for } h < z \qquad (14)$$

where α is a coefficient for vertical entrainment with a value of about 0.4.

2.6 INFORMATION SYSTEM

In addition to the source strength programs and modelling programs the computer contains an information sub-system. This sub-system contains physical and chemical data on priority chemicals. In a previous MOE report "Atmospheric Monitoring for Transportation Emergencies" (ARB-030-81), 79 of these chemicals were identified as posing the highest risk to human health and the environment from transportation-related spills in Ontario. Since that time, more chemicals which could possibly pose a threat to the citizens of Ontario have been added. These chemicals were selected by considering the inherent toxicity of the chemical or its products, and the probability of its being involved in a spill in Ontario.

For each chemical, the following physical and chemical data, where available, are stored in retrievable form:

i) Formula
ii) Molecular weight
iii) Latent Heat of Vapourization (or Sublimation)
iv) Boiling Point - measured at 1 atmosphere
v) Solubility - measured at 0°C unless specified inside brackets
vi) Specific Gravity - with respect to 4°C water at 1.00. (If gaseous, the value reported is that of the liquid in a common compressed state.)
vii) Vapour Pressure - saturated vapour pressure measured at 20°C unless otherwise specified inside brackets
viii) Vapour Density - with respect to air at 1.00.

ix) Flash Point - measurement method coded inside brackets
(CC) closed cup method
(OC) open cup method

x) IDLH - Immediately Dangerous to Life and Health concentration
This is usually defined as a thirty minute exposure. It is used as a guide in the industrial situation as a concentration from which workers would not be able to safely escape if their respiratory equipment failed.

xi) TLV - Threshold Limit Values (Time Weighted Average)
This is defined as the time weighted average concentration for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

xii) STEL - Short Term Exposure Limit
This is defined as a 15-minute time-weighted average exposure which should not be exceeded at any time during a workday even if the eight-hour time-weighted average is within the TLV.

xiii) Specific Heat Ratio - ratio of specific heats of the vapour at constant pressure and at constant volume

xiv) Synonyms - different names for the same chemical

xv) Fire Hazards Code - describes the flammability or combustibility of the chemical and any special hazards posed by its combustion or behaviour in a fire, including toxic products or potential for explosion.

2.7 SYSTEM OUTPUT

The output from the information sub-system is combined with the model calculations to give useful information on potential concentrations of toxic gases downwind of a release. If a critical concentration for human health is entered into the system, a "caution distance" will be calculated. If actual measurements of toxic gas concentrations are made at the site, an emission rate may be estimated.

The Simple Gas Model output can be graphically displayed on the computer terminal, showing downwind concentration in context with TLV and IDLH levels (Threshold Limit Values and Immediately Dangerous to Life and Health values).

The Heavy Gas Model output can be printed on a portable printer, and this output is given for a series of different downwind distances. In addition, it may be plotted if a plotter is available.

CHAPTER 3: USER'S MANUAL

3.1 INFORMATION SYSTEM:

3.1.1 Requirements

The Emergency response program models are implemented on an IBM/PC* compatible system. Minimum system requirements in addition to the basic system are two $5\frac{1}{4}$" disk drives, 640 kilobytes of memory (total), printer and plotter (if plots with better resolution of the output are required). A math co-processor 8087 or 80287 (for AT compatible systems) is advantageous since it reduces the execution time of the programs.

When the system is initially booted (started) the Gas System Menu will appear. Before any model is selected, the user MUST select the chemical which he wants to model from the Information System. After the chemical is selected (if the desired chemical is not in the list then there is provision for adding the chemical name and the associated properties), the user selects which of the gas models he wants to run. The use of GAS SYSTEM MENU, INFORMATION SYSTEM, SIMPLE GAS MODEL and the HEAVY GAS MODEL are described in section 3.3, 3.4, 3.5 and 3.6 respectively.

It is strongly recommended that the user make a copy of the disks before using them for the first time.

3.1.2 Disk Drive Operations

The IBM PC generally has two disk drives. Usually the one on the top or on the left is called drive A and the one on the right or bottom is drive B.

***NOTE:** These computers generate and use radio frequency energy, and if not installed and used properly may cause interference to radio reception.

Please note the following:

1. NEVER ATTEMPT TO REMOVE A DISKETTE from a drive while the disk activity light is on.

2. It is very easy to damage a diskette's surface and lose the information stored on it.

3. Avoid placing the diskette near any magnetic field (this erases all the information).

4. Keep all exposed surfaces protected from dust and contact with other foreign materials. Keep the diskette inside its paper envelope unless it is being used in the drive.

5. Store diskette in a cool, clean, dry place.

6. Do not touch the magnetic surface with your fingers.

3.2 GAS SYSTEM

3.2.1 Set Up Procedure

GAS SYSTEM consists of several basic programs and some data files. They are stored on the diskette. To start the system, follow this procedure.

1) Turn your computer on. Follow your normal start-up procedures.

2) Insert Disk A into Drive A and Disk B into Drive B.

3) Type A: (return) if you are not on Drive A.

4) Type Autoexec (return).

************ WARNING ************

This program may not run on all basic interpreters or compilers.

****

5) A disclaimer should appear on your screen. You should read it carefully the first time you use the program.

6) Press any key after reading the disclaimer and a menu like the one depicted below should appear.

```
********************
* GAS SYSTEM MENU  *
********************

1. FOR INFORMATION ACCESS
2. FOR SOURCE STRENGTH EST.
3. FOR METINFO.
4. FOR SIMPLE GAS MODEL
5. FOR HEAVY GAS MODEL
6. EXIT

SELECT →
```

7) Pressing (1)* will give you access to the information system. **If you do not run this now, you will be using parameters for whatever gas was modelled by the previous user of the program.**

8) Follow the instructions in the succeeding sections to run the various programs.

9) When finished and the GAS SYSTEM MENU appears on the screen, press 6 to exit. Type "system" to exit most Basic interpreters.

10) Remove the diskettes from the computer and place them in their envelopes.

3.2.2 Normal Operation Steps in Case of Emergency

1) Run the information Sub-system to look for the chemical in question. The system will store the properties of the located chemical in a data file (JINFO.DAT) for later reference by the models. If the chemical is not in the list, consult other emergency response handbooks. New chemicals may easily be added to your list.

2) If you do not know the source strength, press (2) at the Gas System menu and an estimation program will enable you to determine an approximate value.

---

*Note: Single keystrokes will be denoted by a character or phrase inside brackets. Thus (1) indicates the computer key with 1 on it - a lower case L will not be interpreted by the computer as a 1. (Return) is the key near the right hand side of the computer which may be marked RETURN, or ENTER, or with a small arrow such as <┘.

Upper case letters indicate the letter in question while lower case letters are variables which in general stand for a number.

3) Run the Simple Gas Model. If you have run the source strength routine, the computer will use the value as a default.

4) If the release is instantaneous and time permits you can run the heavy gas model to obtain a more realistic estimate of downwind concentrations.
NOTE: If you are going to run the heavy gas model, you must run the **Metinfo** system first.

3.3 INFORMATION SYSTEM

The Information System consists of a set of programs and files (See Chapter 4) to provide information on physical and chemical properties of various hazardous chemicals. The system consists of 5 routines:

the Display Routine,
the Add Routine,
the Delete Routine,
the Modify Routine, and
the Change Routine.

The DISPLAY ROUTINE finds and exhibits selected physical and chemical properties, synonyms, and fire hazard codes of the requested chemical compound if it is in the Information File.

The ADD ROUTINE is used to put a new chemical compound into the Information File. The user must provide all information in standard units displayed.

The DELETE ROUTINE removes an entire gas record from the information system, together with all its synonyms. EXTREME CAUTION should be exercised with this.

The MODIFY ROUTINE allows the user to add physical or chemical properties to all the records in the Information File.

The CHANGE ROUTINE allows a user to alter the value of one or more fields of the requested chemical; or to put in the value of a new field added by the MODIFY ROUTINE.

************ WARNING ************

Take extreme care while running the ADD, DELETE and MODIFY routines. They alter the file structure and mistakes cannot be easily undone.

****

3.3.1 Getting Into Routines

After pressing (1) at the GAS SYSTEM MENU and shortly after a **"PLEASE WAIT A MINUTE"** message is displayed, the Main Selections Display for the Information Sub-system will appear as below:

```
**********************
* INFORMATION ACCESS *
**********************

1.  DISPLAY   INFORMATION ON SPECIFIED CHEMICAL
2.  ADD       ADD NEW CHEMICAL
3.  MODIFY    ADD NEW PROPERTY
4.  HELP      HOW TO USE THIS PROGRAM
5.  EXIT      TO GAS SYSTEM MENU


    SELECT -->
```

To get into the DISPLAY ROUTINE, type (1) and press the RETURN key.

You will then be offered the choice of two ways of finding the chemical you wish to model. Pressing (1) allows you to scan the entire list in pages of 20 chemicals (see next section). Pressing (2) will cause the prompt "ENTER KEYWORD OF CHEMICAL:" to appear. You may then type in the chemical name (or part of a name). The computer will then scan the list of chemicals and synonyms and print any names which correspond with your keyword, together with a corresponding number as in the example below:

```
Enter keyword of the chemical:  CHLORINE

164  CHLORINE
165  CHLORINE CYANIDE
166  CHLORINE DIOXIDE
167  CHLORINE TRIFLUORIDE

SELECT →
```

You may then choose one of these numbers or return to the INFORMATION SYSTEM MENU by typing (E).

When this Main Selection Display is on the screen, any illegal commands entered by the user will cause a self-explanatory message to appear beside the arrow. These error messages will disappear shortly so you may continue or try to enter another command.

3.3.2 Display Routine

The first 20 chemical names of the Synonym Table (see Appendix I) will be displayed.

```
 1   2 BUTENAL
 2   ACETADLDEHYDE
 3   ACETALDOL
 4   ACETIC ACID
 5   ACETIC ACID ALLYL ESTER
 6   ACETIC ACID ISOPROPYL ESTER
 7   ACETIC ACID METHYL ESTER
 8   ACETIC ANHYDRIDE
 9   ACETIC ETHER
10   ACETIC OXIDE
11   ACETIDIN
12   ACETONE
13   ACETONITRILE
14   ACETONYL CHLORIDE
15   ACETEXUETHANE
16   ACETYLENE DICHLORIDE
17   ACETYLENE TETRACHLORIDE
18   ACRALDEHYDE
19   ACROLEIN
20   ACRYLALDEHYDE

***  TYPE 'H' FOR HELP, ***

SELECT =========>
```

You might not see the chemical name that you want. Therefore, you need to "flip" the page back and forth. In order to see the next page, press the (↓) key or (D) (no RETURN) to see the previous page, press the (↑) key or (U) (no RETURN).

If you want to "flip" more than 1 page at a time, keep the (↑) or (↓) key pressed down until you want to stop and see where you are. Remember that the names are listed in alphabetical order. Typing 'H' at this point will produce helpful instructions.

When you have located the chemical name on the screen, type the index number corresponding to that chemical. (This number is on the left side of the name.) Whatever you type in will appear on the screen to the right of "SELECT" in the bottom line.

If the chemical you wish to model is not in the list, go to the Add Routine.

After you type in the index number, press the RETURN key. The information on the requested chemical will be displayed in the following format.

```
                   *** AMMONIA ANHYDROUS ***

   1     FORMULA                   NH3
   2     MOLECULAR WEIGHT          17.03
   3     LATENT HEAT               1370           kJ/kg
   4     BOILING POINT             -33            deg C
   5     SOLUBILITY                89.9           G/100 ml
   6     SPECIFIC GRAVITY          0.62(LIQ)
   7     VAPOUR PRESSURE           76000(26 C     mm of Hg
   8     VAPOUR DENSITY            0.6
   9     FLASH POINT               NA
  10     IDLH                      355            mg/m3
  11     TLV                       18             mg/m3
  12     STEL                      25             mg/m3
  13     SP HEAT RATIO(VAP)        1.31
  14     SYNONYMS
               1   AMMONIA ANHYDROUS
               2   LIQUID AMMONIA
  15     FIRE HAZARD CODE (PRESS F FOR EXPLANATION)
               3   12

PRESS 'U'NIT, 'C'HANGE, 'D'ELETE, 'P'RINT, 'E'XIT, 'L'IST
```

All the physical and chemical data are stored and presented in standard units as shown. The information access system will provide information in an alternative set of units (shown below) if requested by the user.

AMMONIA ANHYDROUS	NH3	
MOLECULAR WEIGHT	17.03	
LATENT HEAT	327	cal/g
BOILING POINT	-27.4	deg f
SOLUBILITY	89.9	g/100 ml
SPECIFIC GRAVITY	.62	
VAPOUR PRESSURE	76000	mm of Hg
VAPOUR DENSITY	.6	
FLASH POINT	NA	
IDLH	500	ppm
TLV	25	ppm
STEL	35	ppm
SP HEAT RATIO(VAP)	1.31	

In some instances, terms such as "ND", "NF", and "NA" are used. "ND" means that the item could not be found in any of the sources searched. "NF" is used in the Flash Point field and means that the chemical is not flammable and therefore has no flash point. "NA" means that the field is not applicable for the displayed chemical.

The synonyms listed are considered to be the most common, and either the chemical name or the synonyms can be used for accessing the information stored in the system.

At this point, different options are available by pressing the appropriate letters:

(F) - to display the explanation of fire hazard codes (See Appendix II);

(U) - to change the display to the alternative set of units (e.g. IDLH, TLV and STEL in ppm);

(C) - to enter the CHANGE ROUTINE (see below);

(D) - to delete the chemical record;

(P) - to print a hard copy on a printer, if available; The (Prtsc) button performs the same function;

(L) - to redisplay the list of chemical names so that another chemical can be selected;

(E) - to return to the Main Selection Display - any illegal character will have the same effect.

3.3.3 Change Routine

The change routine will list physical and chemical properties, each accompanied by an item number and the appropriate unit. The system will also ask the item number of the property whose value you want to change. After typing the number and pressing the (RETURN) key, the system will allow you to enter the new value of that property and ask whether you want to make more changes. A typical dialogue is shown on the next page.

You can change more than one item though you can only change one at a time. When you respond 'N' to the 'More Changes?' question, the new information will be stored on the diskette and re-displayed on the screen.

```
*** AMMONIA ANHYDROUS ***
 1  FORMULA
 2  MOLECULAR WEIGHT
 3  LATENT HEAT                kJ/kg
 4  BOILING POINT              deg C
 5  SOLUBILITY                 g/100 ml
 6  SPECIFIC GRAVITY
 7  VAPOUR PRESSURE            mm of Hg
 8  VAPOUR DENSITY
 9  FLASH POINT                deg C
10  IDLH                       ppm
11  TLV                        ppm
12  STEL                       ppm
13  SP HEAT RATIO(VAP)
14  SYNONYMS
15  FIRE HAZARD CODE

CHOOSE NUMBER:?   1
 1 FORMULA :  ? NH3
MORE CHANGES?  Y OR N
```

3.3.4 Insert Routine

The system will first ask you to "ENTER NEW CHEMICAL NAME"*. Then it will ask "ENTER SYNONYM - OR (RETURN) IF FINISHED" so that you can enter all the synonyms. After that, the system will establish a new record in the Information File and prompt you to enter values for the physical and chemical properties. Respond with the corresponding data in the units specified inside brackets in the prompt. When finished, the data will be written in the new record which is, in turn, stored on the diskette. The Main Selection Display will then re-appear. The chemical will be inserted in the list alphabetically.

---

*All additions and changes should be typed in CAPITAL letters

3.3.5 Modify Routine

After displaying a list of the existing properties with the default set of units, the system will ask "WHAT DO YOU WANT TO ADD?". Respond with the property you want to include and the system will ask for its units. The new list of properties will be displayed after the modification has been recorded on the diskette. You can then use the DISPLAY ROUTINE to see that a blank space has been reserved for you to put in the value of the property newly included. Do so by invoking the CHANGE ROUTINE (Section 3.3.3).

3.3.6 Delete Routine

When you choose this option, the computer will confirm your choice by asking, "Are you sure (Y/N)?". If you type (Y), it will remove the chemical record from the data files. Note that it will also delete all references under other synonyms so the chemical will no longer be available.

3.4 SIMPLE GAS MODEL

3.4.1 Selection Phase

The Simple Gas Model Menu below allows you to choose between calculations for the Continuous Release (Plume) Case, the Instantaneous Release (Puff) Case or Source Strength Estimation.

This program is highly user-friendly and step-by-step menus or instructions are displayed on the screen. The following is an example for the concentration calculations in the Continuous Release Case. The first step is to type (1) and press the (RETURN) key from this main menu to choose the Continuous Release Case calculation. Make another choice if you want to run another routine. Then follow displayed instructions which guide you in your calculations.

```
****************************************
*                                      *
*          SIMPLE GAS MODEL            *
*                                      *
****************************************


  1.  Continuous Release Case
  2.  Instantaneous Release Case
  3.  Source Emission (Rate) Caln.
  4.  Quit (Exit to GAS SYSTEM MENU)


     SELECT =======>
```

The next menu will allow you to select different routines as shown below:

```
****************************************
*                                      *
*     CONTINUOUS RELEASE MODEL         *
*                                      *
****************************************


  1.  Calculate Concentration.
  2.  Calculate Emission Rate.
  3.  Calculate Caution Distance.
  4.  Quit (Exit to Simple Gas MENU)


     SELECT =======>
```

To get into a routine, type the routine number followed by the RETURN key. For example, if you want to calculate the concentration, type (1) and press (RETURN).

You will be asked for some information. Most of these parameters have default values which may be obtained by pressing (RETURN) without typing anything. Examples of certain answers are displayed below.

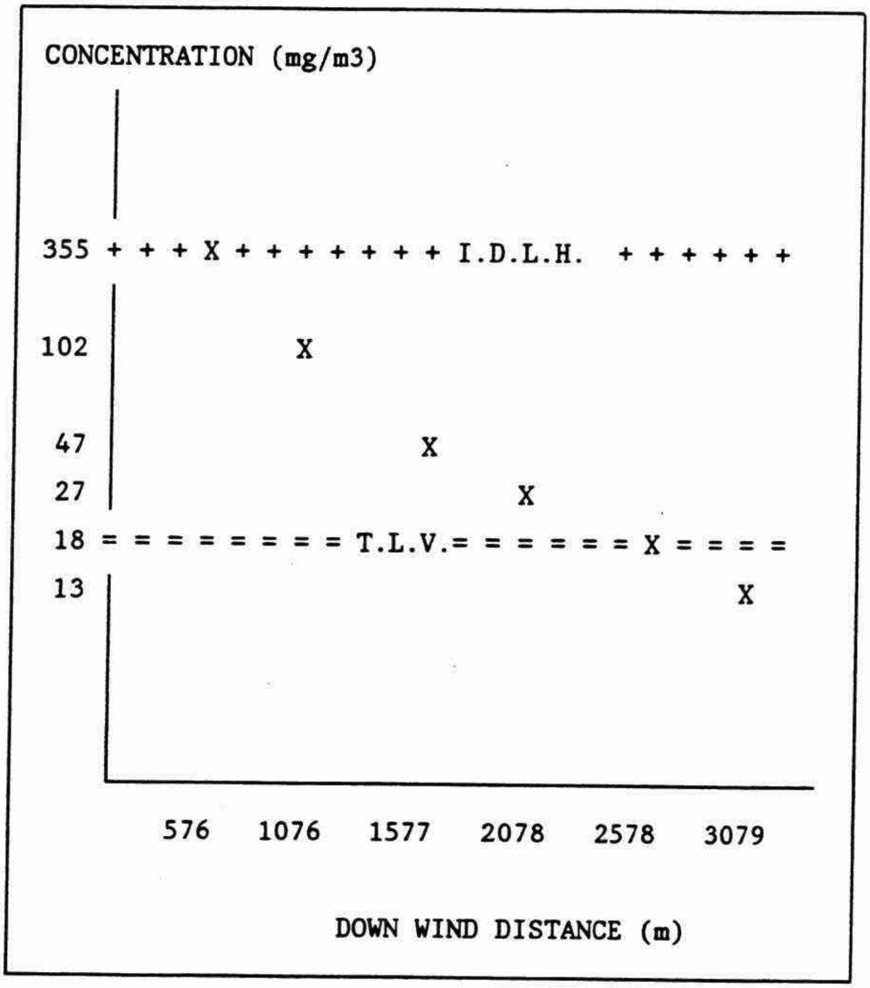
```
      *** CALCULATE CONCENTRATION ***

EMISSION RATE:             20    (kg/sec)
WINDSPEED:                  5    (m/sec)
DOWN-WIND DISTANCE:      5000    (m)
MIXING LAYER HEIGHT:      300    (m)
VERTICAL FLUCT'N:         0.1
HORIZONTAL FLUCT'N:      0.17
TIME ELAPSED:            3600    (Sec)


      *** PRESS ANY KEY TO CONTINUE ***
```

3.4.3 Output Phase

The answer is given in two different units as shown below. To put this concentration into perspective, the IDLH, STEL and TLV values are also quoted in (mg/m^3).

```
**************
CONCENTRATION
**************

7.34314                                  (mg/m3)
4.89688E-07                              (lb./ft3)

*** IDLH:            354.8               (mg/m3) ***
*** STEL:             24.8               (mg/m3) ***
*** TLV:              17.7               (mg/m/) ***


*****************
PLUME FULL-WIDTH
*****************

1700                 (m)
5577.7               (ft)


  * PRESS 'G' FOR GRAPHICS, 'E' TO EXIT *
```

At this point, a graphic display of concentration against distance can be obtained by pressing (G). Note that the concentration scale is logarithmic. The IDLH and TLV levels are also drawn. The IDLH and TLV distances can be easily read from the graph.



Hard copies of this graph can be obtained by pressing the (PrtSc) key if a printer is available.

3.5 HEAVY GAS MODEL

*** Before this can be used, the METINFO MODULE must be run ***

3.5.1 Input Phase

This model requires the input of 11 parameters. Most of them have default values. These are listed at the beginning of the run. Questions are then presented sequentially as input panels, so that you can supply or change the parameters. A typical input panel is shown below.

```
[Q6] Amount of the Gas Released







ENTER YOUR INPUT HERE  ——>                 (kg)

ENTER        value
             Qn          to jump to Question n
             L           to List all parameters
             <rtn>       to use default value
             R           to Run the model
             E           to Exit
```

The middle area is for receiving input. The upper area displays the default value, if available, and other helpful information. Valid input commands are listed at the bottom. By typing (Q)(n) (RETURN), when n is an integer from 1 to 11 (not the key corresponding to the letter 'n'), you can jump directly to question number 1. Typing (L) (RETURN) will produce a list of the input parameters. Typing (R) (RETURN) or (E) (RETURN) respectively will execute or terminate the model. If you want to use the default value, just press (RETURN). There is no default value for the amount of gas released (Question Q6). The model will not run unless this parameter is supplied.

A typical list of parameters, which will also appear automatically after you answer Question Q11, is as follows:

L I S T   O F   P A R A M E T E R S

CHEMICAL FORMULA : NH_3

[Q 1]	Molecular Weight	17.03	
[Q 2]	Boiling Point	-33	(deg C)
[Q 3]	Latent Heat, Gas	1370	(kJ/kg)
[Q 4]	Initial Radius	45	(m)
[Q 5]	Latent Heat, H_2O	2260	(kJ/kg)
[Q 6]	Release Amount	1234	(kg)
[Q 7]	Gas in Liquid	0.0	
[Q 8]	Vert. Entr. Coef.	0.4	
[Q 9]	Mixing Layer Ht.	300	(m)
[Q 10]	Water Vapour	0.01	
[Q 11]	Display Option	D	

* PRESS ANY KEY TO CONTINUE *

You can request a hardcopy by pressing (PrtSc).

3.5.2 Execution Phase

You enter the execution phase by pressing (R) when an input panel is displayed. The system will ask "INTERMEDIATE RESULTS NEEDED?". Responding with (Y) (RETURN) will result in a series of displays of the intermediate results such as the mass of air entrained, volume, initial height and density of cloud, and end of slumping phase information. You also have the option to override some of these by answering with (Y) (RETURN) when prompted in each case.

Armed with these intermediate results, the system will go on to calculate the cloud characteristics as a function of downwind distance. You will be asked to enter the range and the increment in distance for which you want the calculation done. Results of this calculation are shown in the following table.

* CLOUD CHARACTERISTICS *

Distance Option

DIST. (m)	PASSING-TIME(sec) Tail	Cntr	Head	CONC'N. (mg/m3)	RADIUS (m)	HEIGHT (m)
8	34	7	0	2000000	31	0.7
16	43	10	2	2000000	36	0.5
24	52	12	3	2000000	40	0.4
32	63	15	5	2000000	44	0.3
40	65	18	7	2000000	49	0.3
48	67	21	9	2000000	53	0.2
56	69	24	10	2000000	56	0.2
64	70	28	12	2000000	60	0.2
72	72	32	14	2000000	64	0.2
80	74	36	16	2000000	68	0.1
88	76	40	18	2000000	72	0.1
96	78	44	20	2000000	76	0.1
104	79	49	22	2000000	80	0.1
112	81	53	24	2000000	83	0.1
—> Phase two						
120	83	56	26	743307	86	0.2
128	84	59	29	282769	87	0.6
136	86	61	31	176549	89	0.9
144	88	63	34	128473	91	1.2
152	89	65	37	100800	92	1.5
160	91	67	40	82720	93	1.8

This table of cloud characteristics gives, for each downwind distance, the time after release at which the centre, the head and the tail of the cloud passes through that point. If you prefer, the location of the centre, head and tail of cloud can be obtained as a function of time by selecting the time option in question 11.

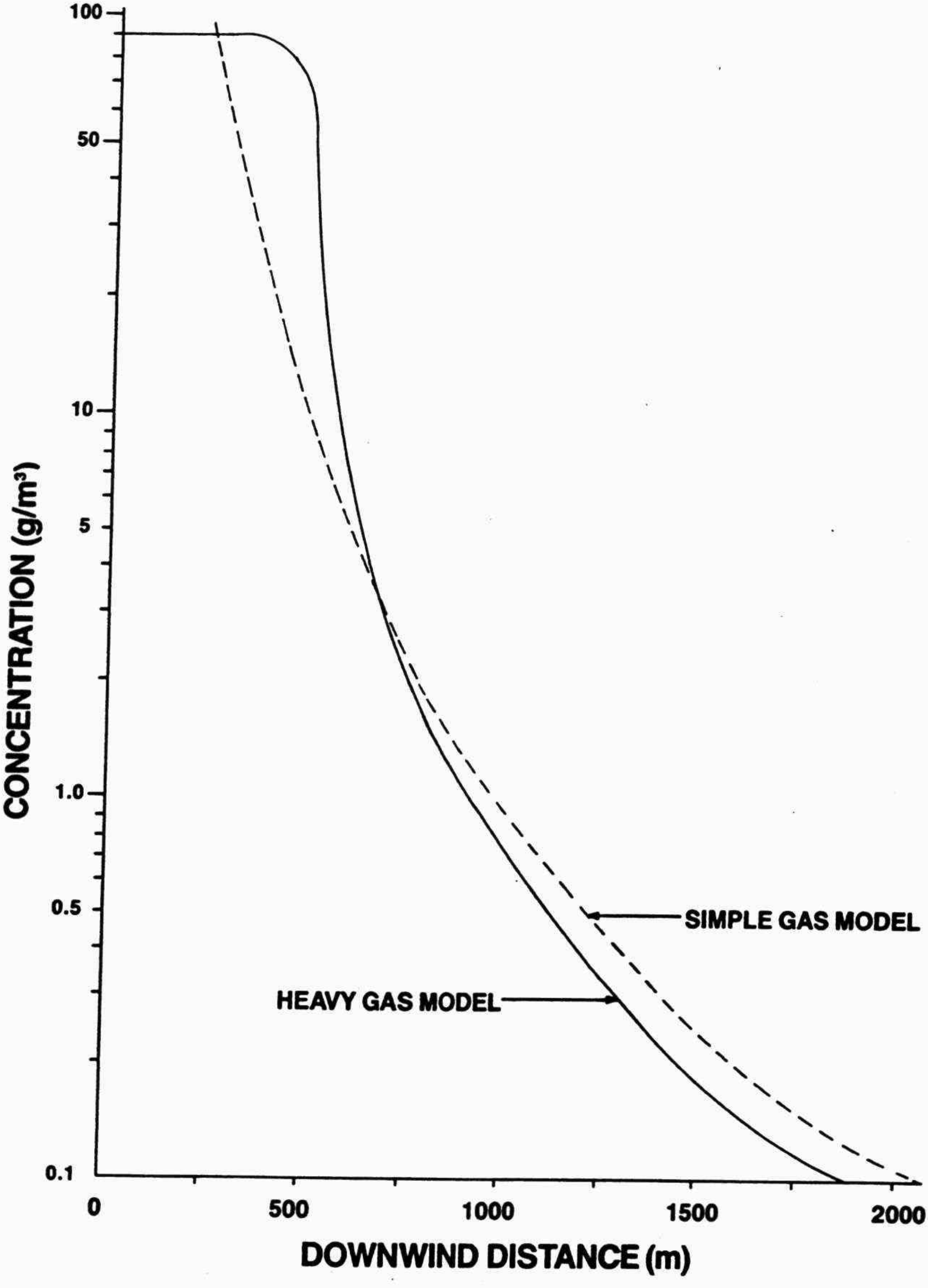
Results are then displayed as in the following table. The difference of the latter two times gives the time of exposure. The display also gives the toxic gas concentration at the cloud centre, the radius and height of the cloud when the cloud is centred at that particular distance. For comparison, the IDLH, STEL and TLV values are displayed on the screen.

* CLOUD CHARACTERISTICS *

Time Option

TIME (sec)	CLOUD-LOCATION(m) Tail	Cntr	Head	CONC'N. (mg/m3)	RADIUS (m)	HEIGHT (m)
0	-7	0	7	2000000	7	13.8
5	-22	4	30	2000000	26	0.9
10	-21	16	53	2000000	37	0.5
15	-14	31	75	2000000	45	0.3
20	-7	44	95	2000000	51	0.2
25	-1	56	113	2000000	57	0.2
30	4	67	130	2000000	63	0.2
35	10	77	145	2000000	68	0.1
40	15	87	159	2000000	72	0.1
50	24	104	185	2000000	81	0.1
55	28	112	197	2000000	85	0.1
—> Phase two						
60	38	127	215	212270	88	0.8
65	55	147	239	98105	92	1.5
70	74	170	266	60437	96	2.3
75	96	195	295	41979	100	3.0
80	118	222	325	31181	104	3.8
85	142	249	356	24186	107	4.6
90	166	277	389	19343	111	5.3
95	192	307	421	15827	115	6.1
100	218	336	455	13185	119	6.8

Figure 5 is a graph of concentration against downwind distance predicted by both the Heavy Gas Model and the Simple Gas Model for an instantaneous release of 20,000 kg of ammonia. The agreement between the two models is fairly good. During the slumping phase, the concentration predicted by the Heavy Gas Model remains at a constant high value. This is more realistic than the Simple Gas Model, which predicts infinite concentration at zero distance. A plot of the height of the cloud versus time is shown in Figure 6. The height decreases rapidly at the beginning. It drops to a minimum at the end of the slumping phase and then increases again when atmospheric turbulence dominates. This figure agrees reasonably well with Figure 3 in Kaiser and Walker's (1978) paper, which gives a plot of the height as a function of time, using a more "complete" model.



CONCENTRATION (g/m³)
100
50
10
5
1.0
0.5
0.1
0
500
1000
1500
2000
DOWNWIND DISTANCE (m)
SIMPLE GAS MODEL
HEAVY GAS MODEL

FIGURE 5

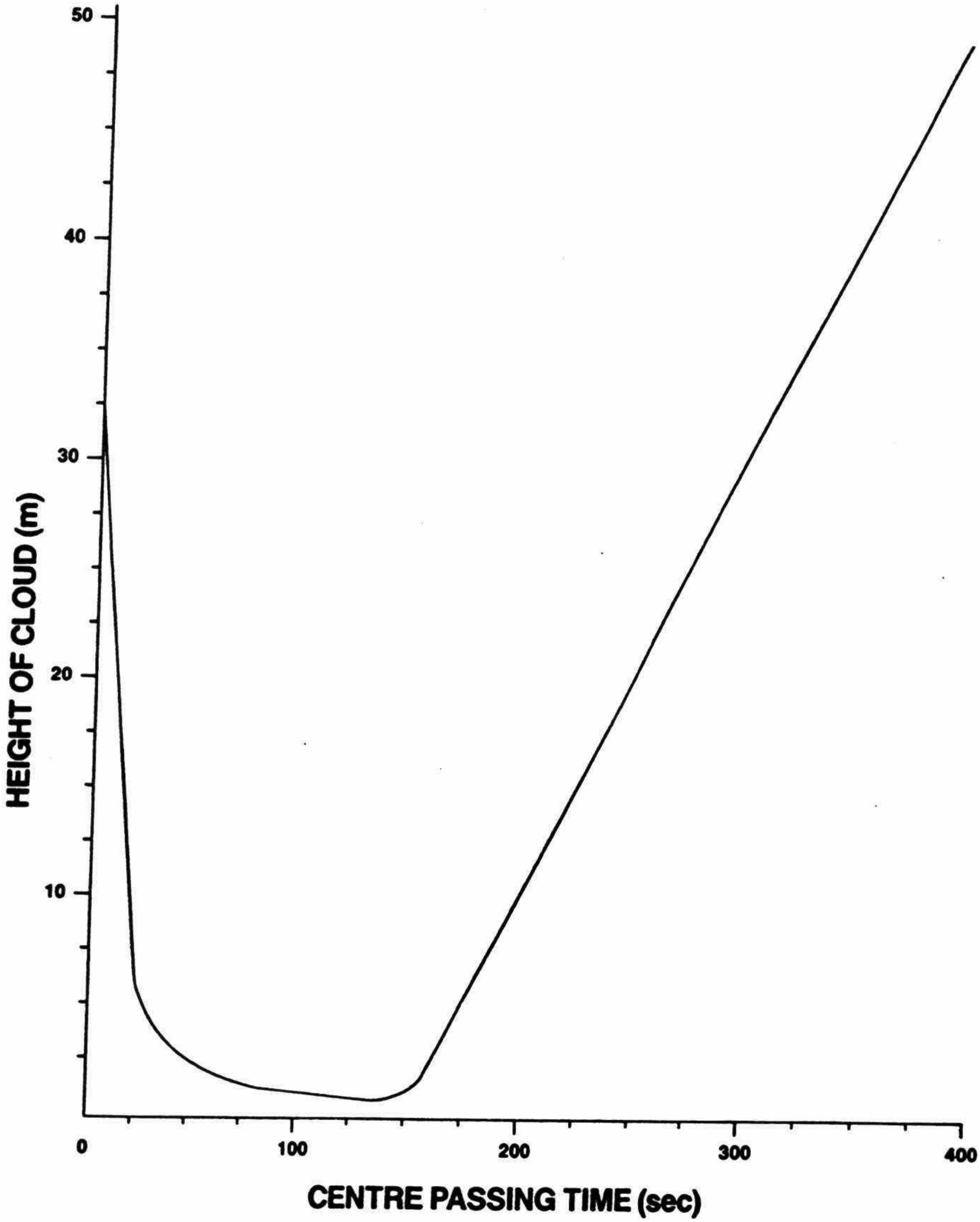

50
40
30
20
10
0
100
200
300
400
HEIGHT OF CLOUD (m)
CENTRE PASSING TIME (sec)

FIGURE 6

3.5.3 Summary of Valid Entries for the Heavy Gas Model

During the input phase you may enter

a number

- any number in the form acceptable by BASIC syntax.

  e.g. 1.1234
  -123.09
  .023
  3.5D2
  7E-3
  -.234E-21

(Q)(n)

- where n is an integer between 1 and 14, to bring you Question n.

(L)

- to list all the parameters with input or default values. Then you can press (P) to get a hardcopy. Note that some physical properties are taken directly from the information access program. The chemical last accessed when you run the INFORMATION ACCESS program is used as default.

(T) or (D)

- Question 11 only. Selects time or distance option.

(R)

- to execute the model.

(E)

- to terminate the model and return to GAS SYSTEM MENU.

3.6 METINFO

The METINFO routine asks the user a series of 9 questions to supply the computer with information needed for the calculations in the heavy gas model.

```
                  *** METEOROLOGICAL INFORMATION ***

 1.  Enter time                                    =     (hh mm)
 2.  Enter date                                    =     (mm dd yy)
 3.  Wind speed at 10 metres                       =     (m/s)
 4.  Temperature at 10 metres                      =     (degree C)
 5.  Atmosphere pressure                           =     (KPa)
 6.  Cloud cover (0 : clear to 8 : overcast)       =
 7.  Longitude of spill location                   =     (degree)
 8.  Latitude of spill location                    =     (degree)
 9.  Surface roughness                             =     (m)
     Default value of No. 1                        =     No
```

Questions 3 - 9 have default values which can be obtained by hitting (RETURN). They may, however, be inappropriate for your location or situation. The default values are previewed in the shaded box on the bottom line.

When you have entered all the values, you will be given a chance to change any you may have mistyped.

The computer will then store the data in a file for the Heavy Gas System to use.

CHAPTER 4: PROGRAMS

4.1 SYSTEM DESIGN AND FLOW CHARTS

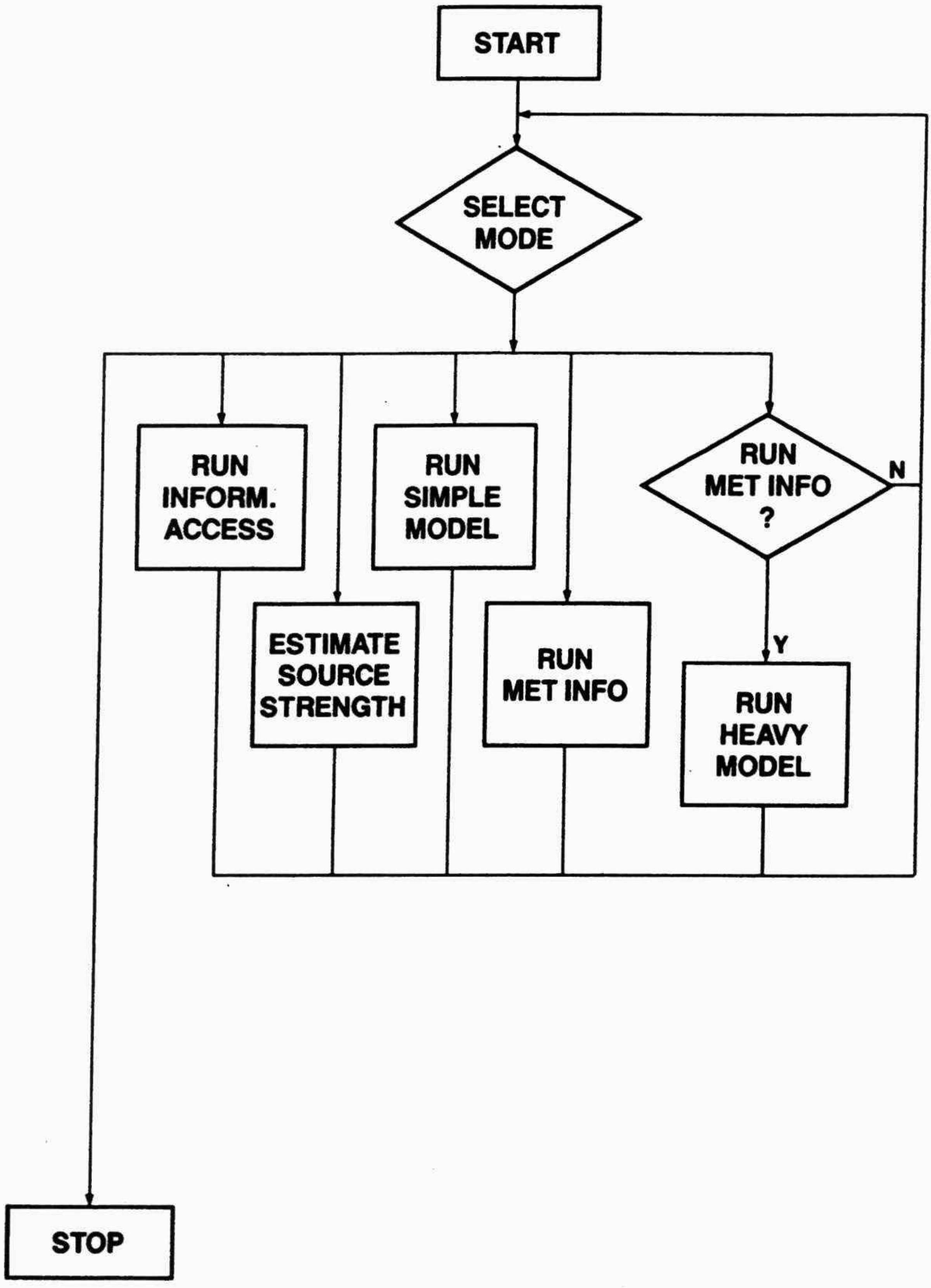
This version of the Portable Computing System for Use in Toxic Gas Emergencies (the GAS SYSTEM) was developed for use in an IBM/PC micro-computer, with two-sided floppy disk drives. If a hard disk is available, the programs and files may be transferred to it. It requires 640K of random access memory. The programs are interactively written in Basic using the MS-DOS (or equivalent) operating system. Programs and files are stored on two 5¼ inch double-density diskettes along with an advanced Basic interpreter and some utility program modules.

The GAS SYSTEM is menu-driven and consists of the following three main programs:

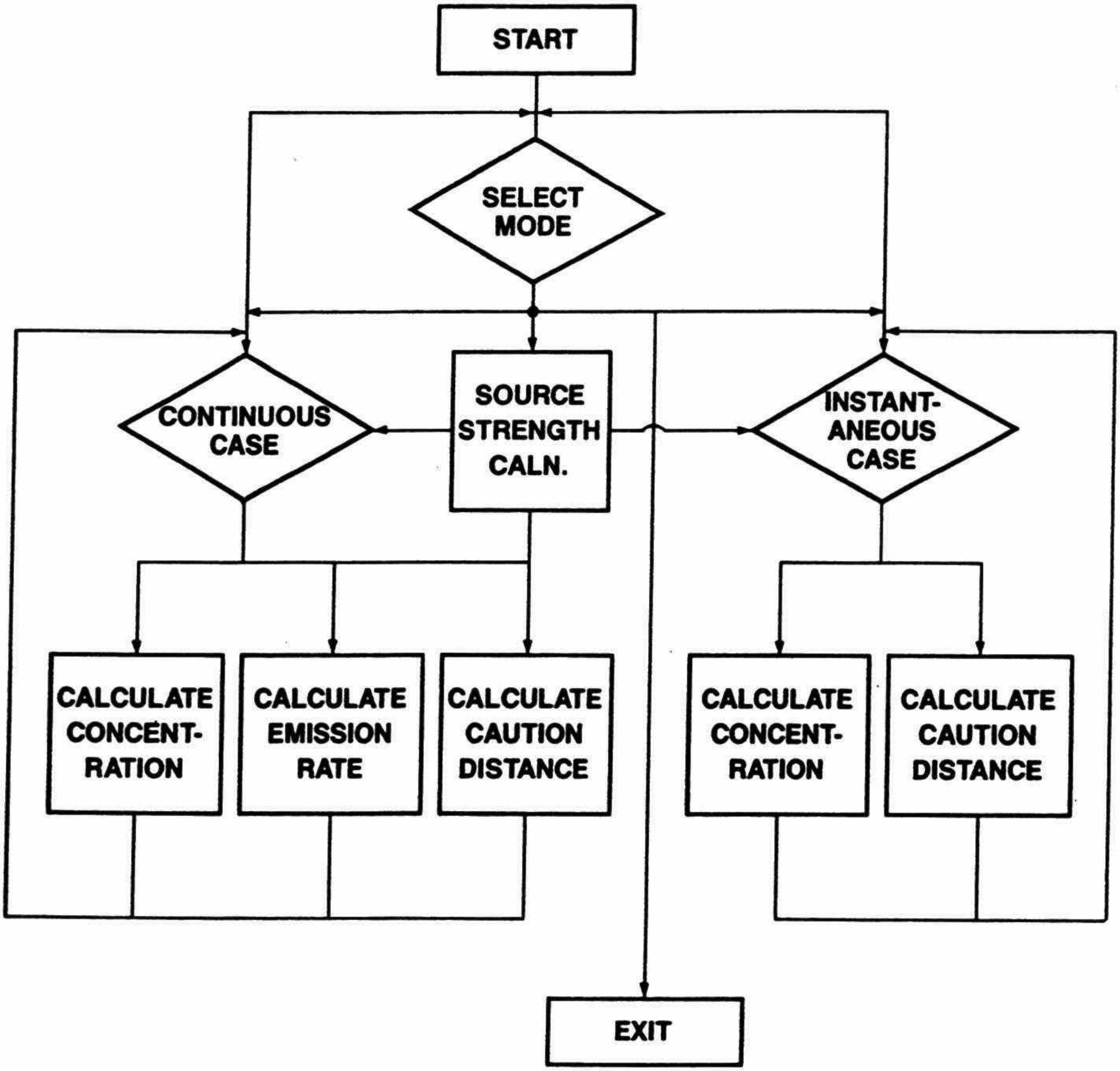
1) SIMPLE - the Simple Gas Model
2) HEAVY3 - the Heavy Gas Model
3) INFO2 - the Information Sub-System

Flow charts on the following pages outline the functions of various programs and routines, as well as their inter-relationship. More detailed description is given in the User's Manual (Chapter 3).

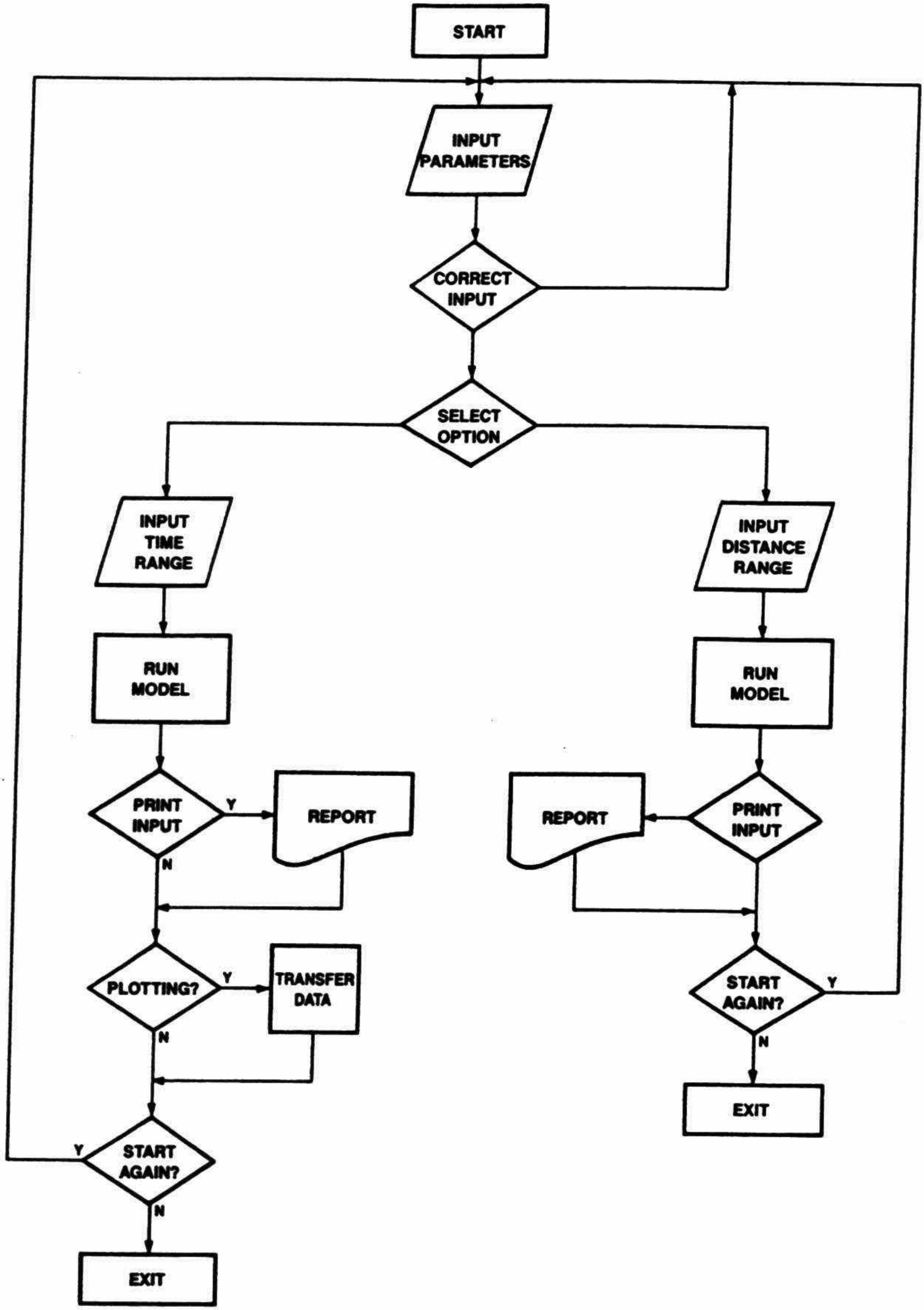
GAS SYSTEM


START
SELECT MODE
RUN INFORM. ACCESS
ESTIMATE SOURCE STRENGTH
RUN SIMPLE MODEL
RUN MET INFO
RUN MET INFO ?
N
Y
RUN HEAVY MODEL
STOP

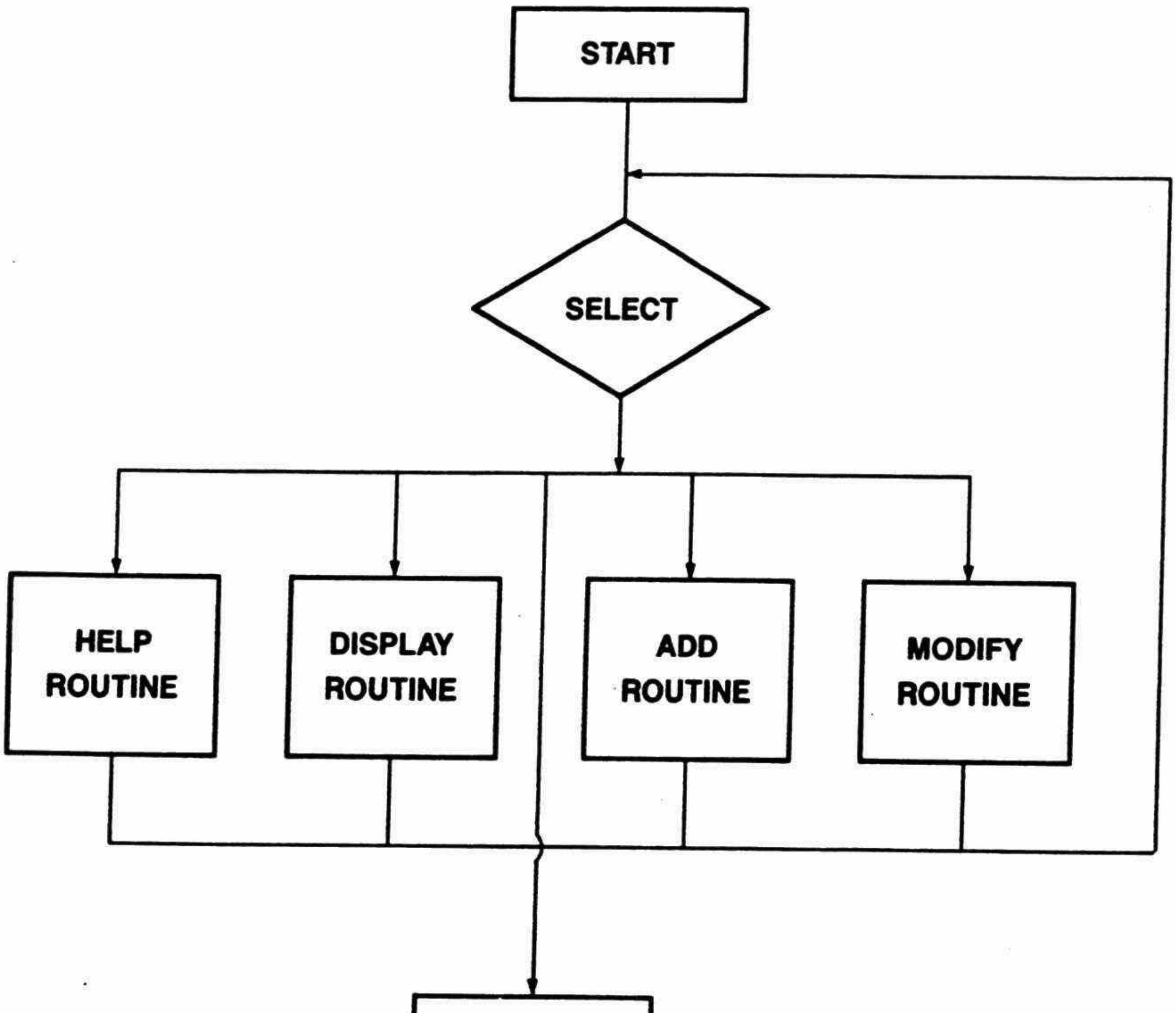
SIMPLE GAS MODEL



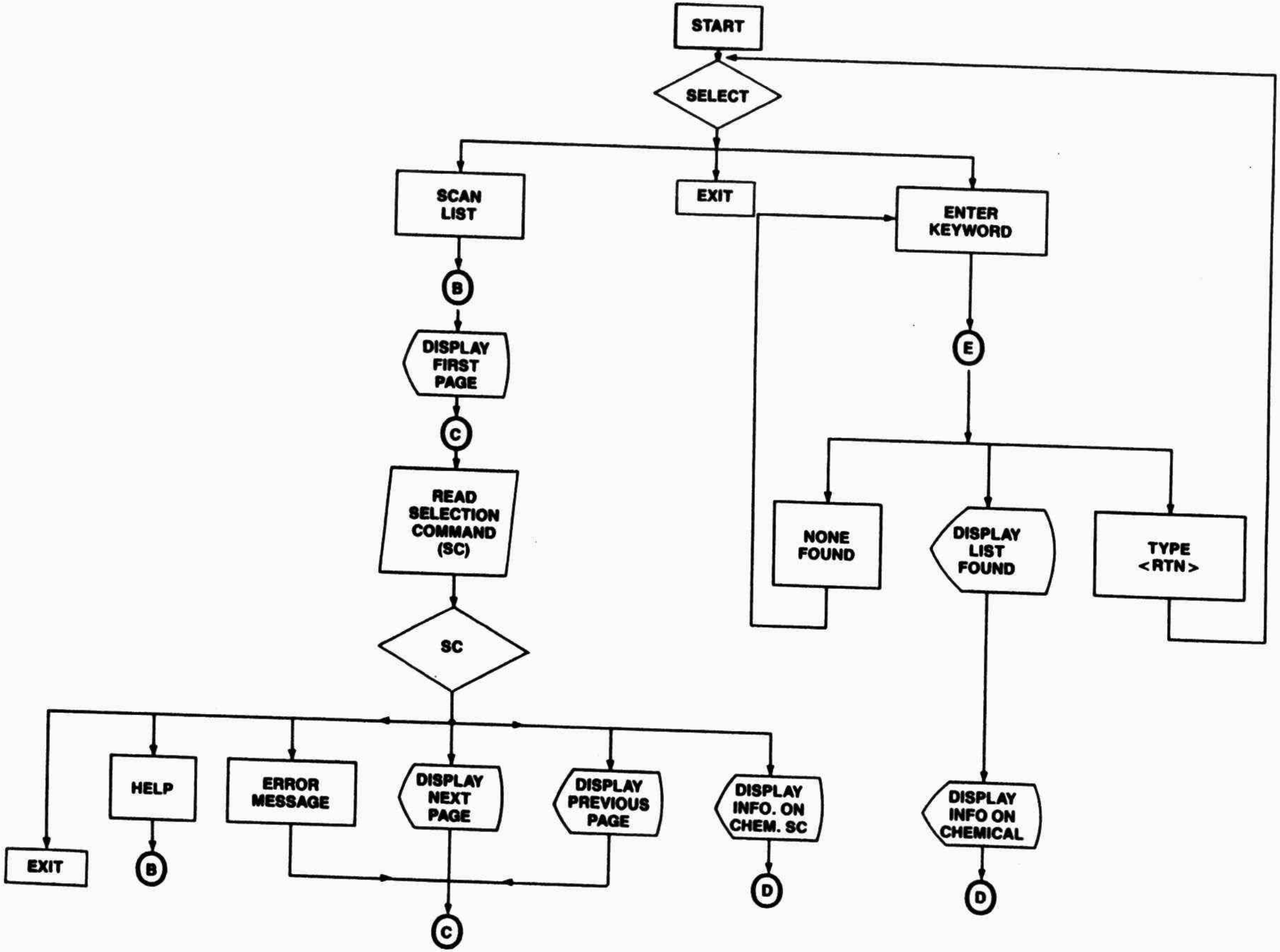
HEAVY GAS MODEL



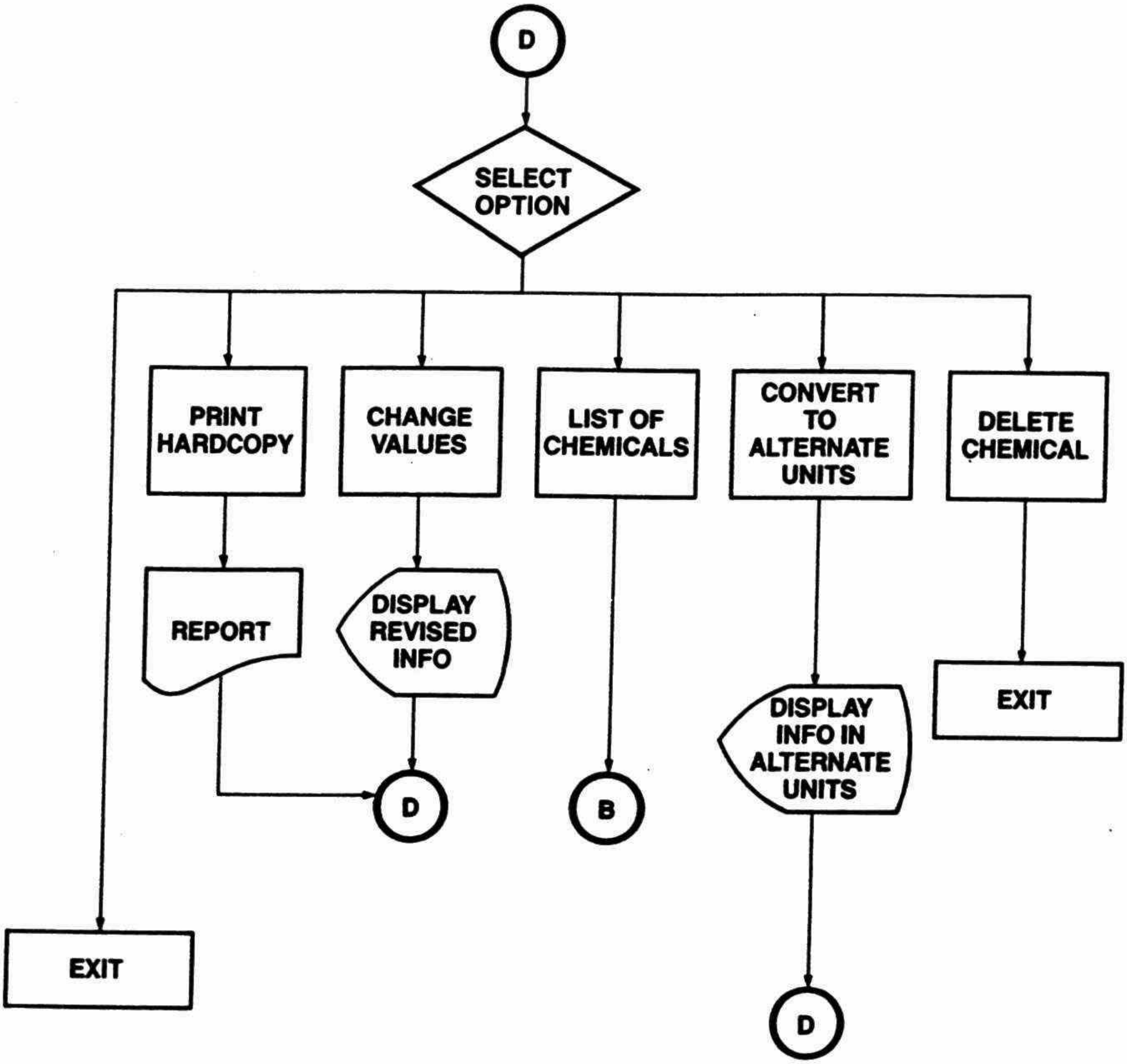
INFORMATION SYSTEM



DISPLAY ROUTINE



DISPLAY ROUTINE (CONT.)



4.2 FILE STRUCTURES FOR INFORMATION SUB-SYSTEM

4.2.1 Information File

This is actually made up by joining two random access files, INFO1.RAF and INFO2.RAF. The resulting file structure has an effective record length of 237 characters distributed among 26 fields as follows:

FIELD	FIELD NAME	LENGTH
1	Chemical Formula	16
2	Molecular Weight	
3	Latent Heat	10
4	Boiling Point	
5	Solubility	16
6	Specific Gravity	
7	Vapour Pressure	
8	Vapour Density	
9	Flash Point	10
10	IDLH	
11	TLV	
12	STEL	
13	Specific Heat Ratio	
14-21	for future expansion	10 each
22-26	Fire Hazard Code	3 each

The chemicals are arranged in alphabetical order, and assigned consecutive record numbers. These are used by the program to retrieve the record containing the information on the respective chemicals.

4.2.2 Chemical Name File

Most of the chemicals have more than one name (synonyms). These various chemical names are stored in a sequential file CHEM.NAM. Each name is paired with the record number used to retrieve the appropriate record from the Information File. The program will load the content of this file into two tables with a common index:

Synonym Table (array STN$) - containing the synonyms.

Synonym Table Link (array STL) - containing the record numbers.

4.2.3 Synonym File

This sequential file, named SYNO.NAM, contains groups of numerical indices delimited by zeros. Each group contains all the indices to retrieve the synonyms of a particular chemical from the Synonym Table (array STN$).

4.2.4 Parameters File

The contents of this sequential file PARA.NAM are labels of the physical and chemical properties (i.e. field names of the Information File) and their associated units.

APPENDIX

I. SYNONYM TABLE

INDEX	SYNONYM	CHEMICAL NAME
1.	2 BUTENAL	CROTON ALDEHYDE
2.	ACETALDEHYDE	ACETALDEHYDE
3.	ACETALDOL	ALDOL
4.	ACETIC ACID	ACETIC ACID
5.	ACETIC ACID ALLYL ESTER	ALLYL ACETATE
6.	ACETIC ACID ISOPROPYL ESTER	ISOPROPYL ACETATE
7.	ACETIC ACID METHYL ESTER	METHYL ACETATE
8.	ACETIC ANHYDRIDE	ACETIC ANHYDRIDE
9.	ACETIC ETHER	ETHYL ACETATE
10.	ACETIC OXIDE	ACETIC ANHYDRIDE
11.	ACETIDIN	ETHYL ACETATE
12.	ACETONE	ACETONE
13.	ACETONITRILE	ACETONITRILE
14.	ACETONYL CHLORIDE	CHLOROACETONE
15.	ACETOXYETHANE	ETHYL ACETATE
16.	ACETYLENE DICHLORIDE	DICHLOROETHYLENE
17.	ACETYLENE TETRACHLORIDE	TETRACHLOROETHANE
18.	ACRALDEHYDE	ACROLEIN
19.	ACROLEIN	ACROLEIN
20.	ACRYLALDEHYDE	ACROLEIN
21.	ACRYLAMIDE	ACRYLAMIDE
22.	ACRYLIC ACID BUTYL ESTER	N-BUTYL ACRYLATE
23.	ACRYLIC ACID ETHYL ESTER	ETHYL ACRYLATE
24.	ACRYLIC ALDEHYDE	ACROLEIN
25.	ACRYLIC AMIDE 50%	ACRYLAMIDE
26.	ACRYLONITRILE	ACRYLONITRILE
27.	ALBONE	HYDROGEN PEROXIDE
28.	ALDOL	ALDOL
29.	ALLTEX	TOXAPHENE
30.	ALLYL ACETATE	ALLYL ACETATE
31.	ALLYL ALCOHOL	ALLYL ALCOHOL

INDEX	SYNONYM	CHEMICAL NAME
32.	ALLYL BROMIDE	ALLYL BROMIDE
33.	ALLYL CHLORIDE	ALLYL CHLORIDE
34.	ALLYL FORMATE	ALLYL FORMATE
35.	ALLYLAMINE	ALLYLAMINE
36.	ALLYLIC ALCOHOL	ALLYL ALCOHOL
37.	ALPHA-DICHLOROPROPIONIC ACID	DICHLOROPROPIONIC ACID
38.	ALUMINUM CHLORIDE	ALUMINUM CHLORIDE
39.	AMINOANISOLE	ANSIDINE
40.	AMINOBENZENE	ANILINE
41.	AMINOBUTANE	BUTYLAMINE
42.	AMINOCAPROIC LACTAM	CAPROLACTAM
43.	AMINOCYCLOHEXANE	CYCLOHEXYLAMINE
44.	AMINOETHANE	ETHYLAMINE
45.	2-AMINOETHANOL	MONOETHANOLAMINE
46.	beta-AMINOETHYL ALCOHOL	MONOETHANOLAMINE
47.	AMINOETHYLENE	ETHYLENEIMINE
48.	AMINOMETHANE	METHYLAMINE
49.	AMINOPROPENE	ALLYLAMINE
50.	AMINOPYRIDINE	AMINOPYRIDINE
51.	AMINOTOLUENE	TOLUIDINE
52.	AMMONIA ANHYDROUS	AMMONIA ANHYDROUS
53.	AMMONIA WATER	AMMONIA HYDROXIDE
54.	AMMONIUM CHLORIDE	AMMONIUM CHLORIDE
55.	AMMONIUM HYDROXIDE	AMMONIUM HYDROXIDE
56.	AMMONIUM MURIATE	AMMONIUM CHLORIDE
57.	n-AMYL ALCOHOL	n-AMYL ALCOHOL
58.	1-AMYL ALCOHOL	n-AMYL ALOCHOL
59.	AMYL ALDEHYDE	VALERALDEHYDE
60.	AMYL HYDRIDE	PENTANE
61.	ANHYDROUS ALUMINUM CHLORIDE	ALUMINUM CHLORIDE
62.	ANILINE	ANILINE
63.	ANILINE OIL	ANILINE
64.	ANILINOBENZENE	DIPHENYLAMINE
65.	ANISIDINE	ANSIDINE
66.	ANSIDINE	ANSIDINE
67.	ANTIMONIC CHLORIDE	ANTIMONY PENTACHLORIDE

INDEX	SYNONYM	CHEMICAL NAME
68.	ANTIMONY PENTACHLORIDE	ANTIMONY PENTACHLORIDE
69.	ANTIMONY PENTAFLUORIDE	ANTIMONY PENTAFLUORIDE
70.	ANTIMONY PERCHLORIDE	ANTIMONY PENTACHLORIIDE
71.	ANTIMONY TRIHYDRIDE	STIBINE
72.	ANTIMONY V	ANTIMONY PENTAFLUORIDE
73.	AQUA FORTIS	NITRIC ACID
74.	AQUALIN	ACROLEIN
75.	AQUALINE	ACROLEIN
76.	AQUEOUS AMMONIA	AMMONIUM HYDROXIDE
77.	AROCLOR	POLYCHLORINATED BIPHENYL
78.	ARSENIC ACID	ARSENIC ACID
79.	ARSENIC ANHYDRIDE	ARSENIC ACID
80.	ARSENIC DICHLOROETHANE	ETHYLDICHLOROARSINE
81.	ARSENIC PENTAOXIDE	ARSENIC ACID
82.	ARSENIC PENTOXIDE	ARSENIC ACID
83.	ASKAREL	POLYCHLORINATED BIPHENYL
84.	ASYM DIMETHYLHYDRAZINE	DIMETHYLHYDRAZINE
85.	AZCYCLOPROPANE	ETHYLENEIMINE
86.	AZIRANE	ETHYLENEIMINE
87.	AZIRIDINE	ETHYLENEIMINE
88.	AZOTIC ACID	NITRIC ACID
89.	BATTERY ACID	SULPHURIC ACID
90.	BENZENE	BENZENE
91.	BENZENETHIOL	PHENYL MERCAPTAN
92.	BENZOL	BENZENE
93.	BENZOLE	BENZENE
94.	BENZYL CHLORIDE	BENZYL CHLORIDE
95.	BETA-CHLOROPRENE	CHLOROPRENE
96.	BICYCLOPENTADIENE	DICYCLOPENTADIENE
97.	BIETHYLENE	BUTADIENE
98.	BISCYCLOPENTADIENE	DICYCLOPENTADIENE
99.	BIVINYL	BUTADIENE
100.	BLUE OIL	ANILINE
101.	BORNANONE	CAMPHOR
102.	BOROETHANE	DIBORANE
103.	BORON CHLORIDE	BORON TRICHLORIDE

INDEX	SYNONYM	CHEMICAL NAME
104.	BORON FLUORIDE	BORON TRIFLUORIDE
105.	BORON HYDRIDE	DIBORANE
106.	BORON TRICHLORIDE	BORON TRICHLORIDE
107.	BORON TRIFLUORIDE	BORON TRIFLUORIDE
108.	BROMALLYLENE	ALLYL BROMIDE
109.	BROMINE	BROMINE
110.	BROMINE PENTAFLUORIDE	BROMINE PENTAFLUORIDE
111.	BROMOETHANE	ETHYL BROMIDE
112.	BROMOETHENE	VINYL ETHENE
113.	BROMOETHYLENE	VINYL ETHYLENE
114.	BROMOFORM	BROMOFORM
115.	BROMOFORME	BROMOFORM
116.	BROMOETHANE	METHYL BROMIDE
117.	BUTADIENE	BUTADIENE
118.	BUTAMINE	BUTYLAMINE
119.	BUTANE	BUTANE
120.	BUTANE NITRILE	BUTYRONITRILE
121.	BUTANETHIOL	BUTYL MERCAPTAN
122.	BUTANOIC ACID ETHYL ESTER	ETHYL BUTYRATE
123.	BUTEN-3-ONE	METHYL VINYL KETONE
124.	BUTYL ACRYLATE	n-BUTYL ACRYLATE
125.	n-BUTYL ACRYLATE	n-BUTYL ACRYLATE
126.	BUTYL ALDEHYDE	BUTYRALDEHYDE
127.	n-BUTYLCARBINOL	n-AMYL ALCOHOL
128.	n-BUTYL 2-PROPENOATE	n-BUTYL ACRYLATE
129.	BUTYL FORMAL	VALERALDEHYDE
130.	BUTYL HYDRIDE	BUTANE
131.	BUTYL MERCAPTAN	BUTYL MERCAPTAN
132.	BUTYL VINYL ETHER	BUTYL VINYL ETHER
133.	BUTYLAMINE	BUTYLAMINE
134.	BUTYRAL	BUTYRALDEHYDE
135.	BUTYRALDEHYDE	BUTYRALDEHYDE
136.	BUTYRIC ACID EHTYL ESTER	ETHYL BUTYRATE
137.	BUTYRIC ALDEHYDE	BUTYRALDEHYDE
138.	BUTYRONITRILE	BUTYRONITRILE
139.	C 56	HEXACHLOROCYCLOPENTADIENE

INDEX	SYNONYM	CHEMICAL NAME
140.	CALCIUM OXIDE	CALCIUM OXIDE
141.	CALX	CALCIUM OXIDE
142.	CAMPHANONE	CAMPHOR
143.	CAMPHECHLOR	TOXAPHENE
144.	CAMPHOR	CAMPHOR
145.	CAPROLACTAM	CAPROLACTAM
146.	CARBANIL	PHENYL ISOCYANATE
147.	CARBOLIC ACID	PHENOL
148.	CARBON BISULPHIDE	CARBON DISULPHIDE
149.	CARBON CHLOROSULPHIDE	THIOPHOSGENE
150.	CARBON DISULPHIDE	CARBON DISULPHIDE
151.	CARBON MONOXIDE	CARBON MONOXIDE
152.	CARBON OXIDE	CARBON MONOXIDE
153.	CARBON OXIDE SULPHIDE	CARBONYL SULPHIDE
154.	CARBON OXYCHLORIDE	PHOSGENE
155.	CARBON OXYSULPHIDE	CARBONYL SULPHIDE
156.	CARBON TET	CARBON TETRACHLORIDE
157.	CARBON TETRABROMIDE	TETRABROMOETHANE
158.	CARBON TETRACHLORIDE	CARBON TETRACHLORIDE
159.	CARBONIC DICHLORIDE	PHOSGENE
160.	CARBONYL CHLORIDE	PHOSGENE
161.	CARBONYL SULPHIDE	CARBONYL SULPHIDE
162.	CHLORALLYLENE	ALLYL CHLORIDE
163.	CHLORINATED BIPHENYL	POLYCHLORINATED BIPHENYL
164.	CHLORINE	CHLORINE
165.	CHLORINE CYANIDE	CYANOGEN CHLORIDE
166.	CHLORINE DIOXIDE	CHLORINE DIOXIDE
167.	CHLORINE TRIFLUORIDE	CHLORINE TRIFLUORIDE
168.	1-CHLORO-2,3-EPOXYPROPANE	EPICHLOROHYDRIN
169.	CHLORO-2-KETOPROPANE	CHLOROACETONE
170.	CHLORO-2-OXOPROPANE	CHLOROACETONE
171.	CHLOROACETALDEHYDE	CHLOROACETALDEHYDE
172.	CHLOROACETONE	CHLOROACETONE
173.	CHLOROACETONITRILE	CHLOROACETONITRILE

INDEX	SYNONYM	CHEMICAL NAME
174.	CHLOROBUTADIENE	CHLOROPRENE
175.	CHLOROCAMPHENE	TOXAPHENE
176.	CHLOROCYAN	CYANOGEN CHLORIDE
177.	CHLOROCYANIDE	CYANOGEN CHLORIDE
178.	CHLOROCYANOGEN	CYANOGEN CHLORIDE
179.	CHLORODIFLUOROMETHANE	CHLORODIFLUOROMETHANE
180.	CHLOROETHANAL	CHLOROACETALDEHYDE
181.	CHLOROETHANE	ETHYL CHLORIDE
182.	CHLOROETHANOL	EHTYLENE CHLOROHYDRIN
183.	CHLOROETHENE	VINYL CHLORIDE
184.	CHLOROETHYLENE	VINYL CHLORIDE
185.	CHLOROFORM	CHLOROFORM
186.	CHLOROFORMIC ACID ISOPROPYL ESTER	ISOPROPYL CHLOROFORMATE
187.	CHLOROFORMYL CHLORIDE	PHOSGENE
188.	CHLOROMETHANE	METHYL CHLORIDE
189.	CHLOROMETHYL CYANIDE	CHLOROACETONITRILE
190.	CHLOROMEHTYLBENZENE	BENZYL CHLORIDE
191.	CHLOROPENTAFLUOROETHANE	CHLOROPENTAFLUOROETHANE
192.	CHLOROPHENYLMETHANE	BENZYL CHLORIDE
193.	CHLOROPICRIN	CHLOROPICRINE
194.	CHLOROPICRINE	CHLOROPICRINE
195.	CHLOROPRENE	CHLOROPRENE
196.	gamma-CHLOROPROPYLENE OXIDE	EPICHLOROHYDRIN
197.	CHLOROPYRIDINE	CHLOROPYRIDINE
198.	CHLOROSULPHONIC ACID	CHLOROSULPHONIC ACID
199.	CHLOROTOLUENE	BENZYL CHLORIDE
200.	CHLOROTRIMETHYLSILANE	TRIMETHYLCHLOROSILANE
201.	CHLORSULPHONIC ACID	CHLOROSULPHONIC ACID
202.	CHLORURE DE CYANOGENE	CYANOGEN CHLORIDE
203.	CLAIRSIT	PERCHLOROMETHYLMERCAPTAN
204.	CMDP	MEVINPHOS
205.	COAL GAS	CARBON MONOXIDE
206.	CRESOLS	CRESOLS
207.	CRESYLIC ACID	CRESOLS
208.	CROTONAL	CROTONALDEHYDE
209.	CROTONALDEHYDE	CROTONALDEHYDE

INDEX	SYNONYM	CHEMICAL NAME
210.	CROTONIC ALDEHYDE	CROTONALDEHYDE
211.	CUMENE	ISOPROPYL BENZENE
212.	CYANOETHANE	PROPIONITRILE
213.	CYANOGEN	CYANOGEN
214.	CYANOGEN CHLORIDE	CYANOGEN CHLORIDE
215.	CYANOGRAN	SODIUM CYANIDE
216.	CYANOETHYLENE	ACRYLONITRILE
217.	CYANOMETHANE	ACETONITRILE
218.	CYCLOHEPTATRIENE	CYCLOHEPTATRIENE
219.	CYCLOHEXANE	CYCLOHEXANE
220.	CYCLOHEXYAMINE	CYCLOHEXYAMINE
221.	CYCLOPENTANE	CYCLOPENTANE
222.	2,4-D	2,4-DICHLOROPHENOXYACETIC ACID
223.	DALAPON	DICHLOROPROPIONIC ACID
224.	DCPD	DYCYCLOPENTADIENE
225.	DI-N-AMYLAMINE	DI-N-AMYLAMINE
226.	DIAMINE	HYDRAZINE
227.	DIAMINOETHANE	ETHYLENEDIAMINE
228.	1,6-DIAMINOHEXANE	HEXAMETHYLENEDIAMINE
229.	DIAMYL AMINE	DI-N-AMYLAMINE
230.	DIBORANE	DIBORANE
231.	DIBORON HEXAHYDRIDE	DIBORANE
232.	1,2-DIBROMOETHANE	ETHYLENE DIBROMIDE
233.	DICHLORIDE	1,4-DICHLOROBENZENE
234.	1,4-DICHLOROBENZENE	1,4-DICHLOROBENZENE
235.	p-DICHLOROBENZENE	1,4-DICHLOROBENZENE
236.	DICHLOROBUTENE	DICHLOROBUTENE
237.	DICHLORODIFLUOROMETHANE	DICHLORODIFLUOROMETHANE
238.	DICHLORODIMETHYLSILANE	DIMETHYLDICHLOROSILANE
239.	1,2-DICHLOROETHANE	ETHYLENE DICHLORIDE
240.	DICHLOROETHANE	DICHLOROETHANE
241.	DICHLOROETHYLARSINE	ETHYLDICHLOROARSINE
242.	DICHLOROETHYLENE	DICHLOROEHTYLENE
243.	DICHLOROFLUOROMETHANE	DICHLOROFLUOROMETHANE
244.	DICHLOROMETHANE	DICHLOROMETHANE
245.	DICHLOROMETHYLARSINE	METHYLDICHLOROARSINE

INDEX	SYNONYM	CHEMICAL NAME
246.	DICHLORONITROETHANE	DICHLORONITROETHANE
247.	2,4-DICHLOROPHENOXYACETIC ACID	DICHLOROPHENOXYACETIC ACID
248.	DICHLOROPROPANE	PROPYLENE DICHLORIDE
249.	DICHLOROPROPENE	DICHLOROPROPENE
250.	DICHLOROPROPIONIC ACID	DICHLOROPROPIONIC ACID
251.	DICHLOROTETRAFLUOROETHANE	DICHLOROTETRAFLUOROETHANE
252.	DICYANOGEN	CYANOGEN
253.	DICYCLOPENTADIENE	DICYCLOPENTADIENE
254.	DIETHYL ETHER	DIETHYL ETHER
255.	DIETHYL KETONE	DIETHYL DETONE
256.	DIETHYL OXIDE	DIETHYL ETHER
257.	DIETHYL SULPHIDE	DIETHYL SULPHIDE
258.	DIETHYLAMINE	DIETHYLAMINE
259.	DIETHYLENE ETHER	DIOXANE
260.	DIETHYLENEIMIDE OXIDE	MORPHOLINE
261.	DIETHYLETHANAMINE	DIETHYLAMINE
262.	DIETHYLTHIOETHER	DIETHYL SULPHIDE
263.	DIFLUOROCHLOROMETHANE	CHLORODIFLUOROMETHANE
264.	DIFLUOROMONOCHLOROMETHANE	CHLORODIFLUOROMETHANE
265.	DIHYDROGEN SELENIDE	HYDROGEN SELENIDE
266.	DIISOBUTYLAMINE	DIISOBUTYLAMINE
267.	DIISOBUTYLENE	DIISOBUTYLENE
268.	DIISOPROPYL ETHER	DIISOPROPYL ETHER
269.	DIISOPROPYL OXIDE	DIISOPROPYL ETHER
270.	DIISOPROPYLAMINE	DIISOPROPYLAMINE
271.	DIMETHOXYMETHANE	METHYLAL
272.	DIMETHYL ACETIC ACID	ISOBUTRIC ACID
273.	DIMETHYL ETHER	DIMETHYL ETHER
274.	DIMETHYL FORMALDEHYDE	ACETONE
275.	DIMETHYL KETONE	ACETONE
276.	DIMETHYL MONOSULPHATE	DIMETHYL SULPHATE
277.	DIMETHYL PARATHION	METHYL PARATHION
278.	DIMETHYL SULPHATE	DIMETHYL SULPHATE
279.	DIMETHYL SULPHIDE	DIMETHYL SULPHIDE
280.	DIMETHYLACETONE	DIETHYL KETONE
281.	DIMETHYLAMINE	DIMETHYLAMINE

INDEX	SYNONYM	CHEMICAL NAME
282	DIMETHYLAMINO BENZENE	DIMETHYLANILINE
283	DIMETHYLANILINE	DIMETHYLANILINE
284	DIMETHYLBENZENES	XYLENES
285	DIMETHYLDICHLOROSILANE	DIMETHYLDICHLOROSILANE
286	DIMETHYLENEIMINE	ETHYLENEIMINE
287	DIMETHYLFORMAL	METHYLAL
288	DIMETHYLHYDRAZINE	DIMETHYLHYDRAZINE
289	DIMETHYLPHENYLAMINE	DIMETHYLANILINE
290	DINITROBENZENE	DINITROBENZENE
291	DINITROTOLUENE	DINITROTOLUENE
292	DINITROTOLUOL	DINITROTOLUENE
293	DIOXAN	DIOXANE
294	DIOXANE	DIOXANE
295	DIOXANNE	DIOXANNE
296	DIPHENYLAMINE	DIPHENYLAMINE
297.	DIPHENYLMETHANEDIISOCYANATE	DIPHENYLMETHANEDIISOCYANATE
298.	DIPHENYLMETHANE-4, 4-DIISOCYANATE	DIPHENYLMETHANEDIISOCYANATE
299.	DIPROPYLMETHANE	HEPTANE
300.	DIVINYL ETHER	DIVINYL ETHER
301.	DMH	DIMETHYLHYDRAZINE
302.	DMS	DIEMTHYL SULPHATE
303.	DOWICIDE	PENTACHLOROPHENOL
304.	EB	ETHYLBENZENE
305.	EDB	ETHYLENE DIBROMIDE
306.	EDC	ETHYLENE DICHLORIDE
307.	EI	EHTYLENEIMINE
308.	ELEMENTAL PHOSPHORUS	PHOSPHORUS
309.	ENT-50324	ETHYLENEIMINE
310.	EPICHLOROHYDRIN	EPICHLOROHYDRIN
311.	1,2-EPOXYETHANE	ETHYLENE OXIDE
312.	1,2-EPOXYPROPANE	PROPYLENE OXIDE
313.	ERYTHENE	BUTADIENE
314.	ETHANAL ACETIC ALDEHYDE	ACETADLDEHYDE
315.	ETHANE PENTACHLORIDE	PENTACHLOROETHANE
316.	ETHANEDIAMINE	ETHYLENEDIAMINE

INDEX	SYNONYM	CHEMICAL NAME
317.	ETHANEDINITRILE	CYANOGEN
318.	ETHANEDIOIC ACID	OXALIC ACID
319.	ETHANENITRILE	ACETONITRILE
320.	ETHANETHIOL	ETHYL MERCAPTAN
321.	ETHANOIC ACID	ACETIC ACID
322.	ETHANOIC ANHYDRIDE	ACETIC ANHYDRIDE
323.	ETHANOLAMINE	MONOETHANOLAMINE
324.	ETHER	DIETHYL ETHER
325.	ETHER CYANATUS	PROPIONITRILE
326.	ETHER HYDROCHLORIC	ETHYL CHLORIDE
327.	ETHOXYCARBONYLETHYLENE	ETHYL ACRYLATE
328.	ETHYL 2-PROPENOATE	ETHYL ACRYLATE
329.	ETHYL ACETATE	ETHYL ACETATE
330.	ETHYL ACETONE	METHYL PROPYL KETONE
331.	ETHYL ACRYLATE	ETHYL ACRYLATE
332.	ETHYL BROMIDE	ETHYL BROMIDE
333.	ETHYL BUTANOATE	ETHYL BUTYRATE
334.	ETHYL BUTYL ETHER	ETHYL BUTYL ETHER
335.	ETHYL BUTYRATE	ETHYL BUTYRATE
336.	ETHYL CHLOROACETATE	ETHYL CHLOROACETATE
337.	ETHYL CHLOROCARBONATE	ETHYL CHLOROFORMATE
338.	ETHYL CHLOROETHANOATE	ETHYL CHLOROACETATE
339.	ETHYL CHLOROFORMATE	ETHYL CHLOROFORMATE
340.	ETHYL CYANIDE	PROPIONITRILE
341.	ETHYL ETHER	DIETHYL ETHER
342.	ETHYL FORMATE	ETHYL FORMATE
343.	ETHYL FORMIC ESTER	ETHYL FORMATE
344.	ETHYL HYDROSULPHIDE	ETHYL MERCAPTAN
345.	ETHYL MERCAPTAN	ETHYL MERCAPTAN
346.	ETHYL METHACRYLATE	ETHYL METHACRYLATE
347.	ETHYL METHYL KETONE	ETHYL METHYL KETONE
348.	ETHYL NITRATE	NITRIC ETHER
349.	ETHYL PROPENOATE	ETHYL ACRYLATE
350.	ETHYL SILICON TRICHLORIDE	ETHYL TRICHLOROSILANE
351.	ETHYL SULPHYDRATE	ETHYL MERCAPTAN
352.	ETHYL SULPHIDE	DIETHYL SULPHIDE

INDEX	SYNONYM	CHEMICAL NAME
353.	ETHYL THIOALCOHOL	ETHYL THIOALCOHOL
354.	ETHYL n-BUTYRATE	ETHYL BUTYRATE
355.	ETHYL-2-METHYL-2-PROPENOATE	ETHYL METHACRYLATE
356.	ETHYL-2-METHYLACRYLATE	ETHYL METHACRYLATE
357.	ETHYLAMINE	ETHYLAMINE
358.	ETHYLBENZENE	ETHYLBENZENE
359.	ETHYLBENZOL	ETHYLBENZENE
360.	ETHYL CARBINOL	n-PROPYL ALCOHOL
361.	ETHYL CHLORIDE	ETHYL CHLORIDE
362.	ETHYLDICHLOROARSINE	ETHYLDICHLOROARSINE
363.	ETHYLENE ALDEHYDE	ACROLEIN
364.	ETHYLENE BROMIDE	ETHYLENE DIBROMIDE
365.	ETHYLENE CHLORIDE	ETHYLENE DICHLORIDE
366.	ETHYLENE CHLOROHYDRIN	ETHYLENE CHLOROHYDRIN
367.	ETHYLENE DIBROMIDE	ETHYLENE DIBROMIDE
368.	ETHYLENE DICHLORIDE	ETHYLENE DICHLORIDE
369.	ETHYLENE OXIDE	ETHYLENE OXIDE
370.	ETHYLENE TETRACHLORIDE	PERCHLOROETHYLENE
371.	ETHYLENE TRICHLORIDE	TRICHLOROETHYLENE
372.	ETHYLENEDIAMINE	ETHYLENEDIAMINE
373.	ETHYLENEIMINE	ETHYLENEIMINE
374.	ETHYLFORMIC ACID	PROPIONIC ACID
375.	ETHYLIDENE CHLORIDE	DICHLOROETHANE
376.	ETHYLMETHANOATE	ETHYL FORMATE
377.	ETHYLTRICHLOROSILANE	ETHYLTRICHLOROSILANE
378.	FC 114	DICHLOROTETRAFLUOROETHANE
379.	FC 22	CHLORODIFLUOROMETHANE
380.	FERTILIZER ACID	SULPHURIC ACID
381.	FLUORHYDRIC ACID	HYDROFLUORIC ACID
382.	FLUORINE	FLUORINE
383.	FLUOROCARBON 114	DICHLOROTETRAFLUOROETHANE
384.	FLUOROCARBON 22	CHLORODIFLUOROMETHANE
385.	FLUORODICHLOROMETHANE	DICHLOROFLUOROMETHANE
386.	FLUOROETHENE	VINYL FLUORIDE
387.	FLUOROETHYLENE	VINYL FLUORIDE
388.	FORMAL	METHYLAL

INDEX	SYNONYM	CHEMICAL NAME
389.	FORMALDEHYDE	FORMALDEHYDE
390.	FORMALDEHYDE DIMETHYLACETAL	METHYLAL
391.	FORMALDEHYDE POLYMER	PARAFORMALDEHYDE
392.	FORMALIN	FORMALDEHYDE
393.	FORMALITH	FORMALDEHYDE
394.	FORMIC ACID	FORMIC ACID
395.	FORMIC ACID ALLYL ESTER	ALLYL FORMATE
396.	FORMIC ACID ETHYL ESTER	ETHYL FORMATE
397.	FORMIC ACID METHYL ESTER	METHYL FORMATE
398.	FORMIC ALDEHYDE	FORMALDEHYDE
399.	FORMYLIC ACID	FORMIC ACID
400.	FREON 114	DICHLOROTETRAFLUOROETHANE
401.	FREON 115	CHLOROPENTAFLUOROETHANE
402.	FREON 12	DICHLORODIFLUOROMETHANE
403.	FREON 21	DICHLOROFLUOROMETHANE
404.	FREON 22	CHLORODIFLUOROMETHANE
405.	FURAL	FURFURAL
406.	FURAN	FURAN
407.	2-FURANCARBINOL	FURFURYL ALCOHOL
408.	2,5-FURANEDIONE	MALEIC ANHYDRIDE
409.	FURFURAL	FURFURAL
410.	FURFURALCOHOL	FURFURYL ALCOHOL
411.	FURFURALDEHYDE	FURFURAL
412.	FURFURYL ALCOHOL	FURFURYL ALCOHOL
413.	2-FURYL-METHANOL	FURFURYL ALCOHOL
414.	FYDE	FORMALDEHYDE
415.	GAMMA-CHLOROALLYL CHLORIDE	DICHLOROPROPENE
416.	GERMANE	GERMANE
417.	GERMANIUM HYDRIDE	GERMANE
418.	GERMANIUM TETRAHYDRIDE	GERMANE
419.	GLACIAL ACETIC ACID	ACETIC ACID
420.	GLYCOL CHLOROHYDRIN	ETHYLENE CHLOROHYDRIN
421.	GLYCOL EHTYLENE ETHER	DIOXANE
422.	GLYCOMONOCHLOROHYDRIN	ETHYLENE CHLOROHYDRIN
423.	GUM CAMPHOR	CAMPHOR
424.	HALON 2001	ETHYL BROMIDE

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425.	HALON 242	DICHLOROTETRAFLUOROETHANE
426.	HCCPD	HEXACHLOROCYCLOPENTADIENE
427.	HEPTANE	HEPTANE
428.	HEPTANONE	CAMPHOR
429.	HEPTYL HYDRIDE	HEPTANE
430.	HEXACHLOROBUTADIENE	HEXACHLOROBUTADIENE
431.	HEXACHLOROCYCLOPENTADIENE	HEXACHLOROCYCLOPENTADIENE
432.	HEXAFLUOROACETONE	HEXAFLUOROACETONE
433.	HEXAFLUOROPROPENE	HEXAFLUOROPROPYLENE
434.	HEXAFLUOROPROPYLENE	HEXAFLUOROPROYLENE
435.	HEXAHYDROANILINE	CYCLOHEXYLAMINE
436.	HEXAHYDROBENZENE	CYCLOHEXANE
437.	HEXAMETHYLENE	CYCLOHEXANE
438.	HEXAMETHYLENEDIAMINE	HEXAMETHYLENEDIAMINE
439.	HEXANAPHTHENE	CYCLOHEXANE
440.	HEXANE	HEXANE
441.	1,6-HEXANEDIAMINE	HEXAMETHYLENEDIAMINE
442.	HEXONE	METHYL ISOBUTYL KETONE
443.	HEXYL HYDRIDE	HEXANE
444.	HYDRAZINE	HYDRAZINE
445.	HYDRAZINE ANHYDROUS	HYDRAZINE
446.	HYDRAZINE BASE	HYDRAZINE
447.	HYDRAZOMETHANE	METHYLHYDRAZINE
448.	HYDROBROMIC ACID	HYDROGEN BROMIDE
449.	HYDROCHLORIC ACID	HYDROCHLORIC ACID
450.	HYDROCHLORIC ACID ANHYDROUS	HYDROGEN CHLORIDE ANHYDROUS
451.	HYDROCYANIC ACID	HYDROGEN CYANIDE
452.	HYDROCYANIC ACID SODIUM SALT	SODIUM CYANIDE
453.	HYDROCYANIC ETHER	PROPIONITRILE
454.	HYDROFLUORIC ACID	HYDROFLUORIC ACID
455.	HYDROFLUORIC ACID ANHYDROUS	HYDROGEN FLUORIDE
456.	HYDROFLUORIC ACID AQUEOUS	HYDROFLUORIC ACID
457.	HYDROGEN ANTIMONIDE	STIBINE
458.	HYDROGEN BROMIDE	HYDROGEN BROMIDE
459.	HYDROGEN CHLORIDE ANHYDROUS	HYDROGEN CHLORIDE
460.	HYDROGEN CYANIDE	HYDROGEN CYANIDE
461.	HYDROGEN DIOXIDE	HYDROGEN PEROXIDE

INDEX	SYNONYM	CHEMICAL NAME
462.	HYDROGEN FLUORIDE	HYDROGEN FLUORIDE
463.	HYDROGEN PEROXIDE	HYDROGEN PEROXIDE
464.	HYDROGEN PHOSPHIDE	PHOSPHINE
465.	HYDROGEN SELENIDE	HYDROGEN SELENIDE
466.	HYDROGEN SULPHIDE	HDYROGEN SULPHIDE
467.	HYDROXYBENZENE	PHENOL
468.	2-HYDROXYETHYLAMINE	MONOETHANOLAMINE
469.	2-HYDROXYETHYLFURAN	FURFURYL ALCOHOL
470.	HYDROXYTOLUENES	CRESOLS
471.	HYLENE T	TOLUENE-2,4-DIISOCYANATE
472.	IODOMETHANE	METHYL IODIDE
473.	IRON CARBONYL	IRON PENTACARBONYL
474.	IRON PENTACARBONYL	IRON PENTACARBONYL
475.	ISO CYANATOMETHANE	METHYL ISOCYANATE
476.	ISOBUTENE	ISOBUTYLENE
477.	ISOBYTYL METHYL KETONE	METHYL ISOBUTYL KEYTONE
478.	ISOBYUTYLENE	ISOBUTYLENE
479.	ISOBUTYRIC ACID	ISOBUTYRIC ACID
480.	ISOBUTYRONITRILE	ISOBUTYRONITRILE
481.	ISOCYANATOBENZENE	PHENYL ISOCYANATE
482.	ISOCYANIC ACID	METHYL ISOCYANATE
483.	ISOCYANIC ACID PROPYL ESTER	PROPYL ISOCYANATE
484.	ISOPROPANETHIOL	ISOPROPANETHIOL
485.	ISOPROPYL ACETATE	ISOPROPYL ACETATE
486.	ISOPROPYL BENZENE	ISOPROPYL BENZENE
487.	ISOPROPYL BORATE	TRIISOPROPYL BORATE
488.	ISOPROPYL CHLOROCARBONATE	ISOPROPYL CHLOROFORMATE
489.	ISOPROPYL CHLOROFORMATE	ISOPROPYL CHLOROFORMATE
490.	ISOPROPYL CHLOROMETHANOATE	ISOPROPYL CHLOROFORMATE
491.	ISOPROPYL CYANIDE	ISOBUTYRONITRILE
492.	ISOPROPYL ETHER	DIISOPROPYL ETHER
493.	ISOPROPYL MERCAPTAN	ISOPROPANETHIOL
494.	ISOPROPYLACETONE	METHYL ISOBUTYL KETONE
495.	ISOPROPYLAMINE	ISOPROPYLAMINE
496.	ISOPROPYLTHIOL	ISOPROPYTHIOL
497.	KETONE PROPANE	ACETONE
498.	LAUREL CAMPHOR	CAMPHOR

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499.	LEAD TETRAETHYL	TETRAETHYL LEAD
500.	LEAD TETRAMETHYL	TETRAMETHYL LEAD
501.	LEVOXINE	HYDRAZINE
502.	LIQUID AMMONIA	AMMONIA ANHYDROUS
503.	MALEIC ANHYDRIDE	MALEIC ANHYDRIDE
504.	MDI	DIPHENYLMETHANEDIISOCYANATE
505.	MEK	ETHYL METHYL KETONE
506.	MERCAPTOETHANE	EHTYL MERCAPTAN
507.	MERCAPTOMETHANE	METHYL MERCAPTAN
508.	MERCURIALIN	METHYLAMINE
509.	METHACETONE	DIETHYL KETONE
510.	METHACRYLALDEHYDE	METHACRYLALDEHYDE
511.	METHACRYLIC ACID METHYL ESTER	METHYL METHACRYLATE
512.	METHANAL	FORMALDEHYDE
513.	METHANE TETRABROMIDE	TETRABROMOETHANE
514.	METHANESULFENIC ACID	PERCHLOROMETHYLMERCAPTAN
515.	METHANETHIOL	METHYL MERCAPTAN
516.	METHANOIC ACID	FORMIC ACID
517.	METHENYL TRIBROMIDE	BROMOFORM
518.	METHOXYANILINE	ANSIDINE
519.	METHOXYETHENE	VINYL METHYL ETHER
520.	METHOXYETHYLENE	VINYL METHYL ETHER
521.	METHOXYPHENYLAMINE	ANSIDINE
522.	METHYL ACETATE	METHYL ACETATE
523.	METHYL AZIRIDINE	PROPYLENEIMINE
524.	METHYL BROMIDE	METHYL BROMIDE
525.	METHYL CHLOROCARBONATE	METHYL CHLOROFORMATE
526.	METHYL CHLOROFORMATE	METHYL CHLOROFORMATE
527.	METHYL ETHANOATE	METHYL ACETATE
528.	METHYL ETHER	DIMETHYL ETHER
529.	METHYL ETHYL KETONE	ETHYL METHYL KETONE
530.	METHYL FORMATE	METHYL FORMATE
531.	METHYL IODIDE	METHYL IODIDE
532.	METHYL ISOBUTYL KETONE	METHYL ISOBUTYL KETONE
533.	METHYL ISOCYANATE	METHYL ISOCYANATE
534.	METHYL KETONE	ACETONE

INDEX	SYNONYM	CHEMICAL NAME
535.	METHYL MERCAPTAN	METHYL MERCAPTAN
536.	METHYL METHACRYLATE	METHYL METHACRYLATE
537.	METHYL METHACRYLATE MONOMER	METHYL METHACRYLATE
538.	METHYL NITRITE	METHYL NITRITE
539.	METHYL PARATHION	METHYL PARATHION
540.	METHYL PHOSPHITE	TRIMETHYLPHOSPHITE
541.	METHYL PROPENE	ISOBUTYLENE
542.	METHYL PROPYL KETONE	METHYL PROPYL KETONE
543.	METHYL SULPHYDRATE	METHYL MERCAPTAN
544.	METHYL VINYL ETHER	VINYL METHYL ETHER
545.	METHYL VINYL KETONE	METHYL VINYL KETONE
546.	METHYL-2 PROPIONITIRLE	ISOBUTYRONITRILE
547.	METHYLACETIC ACID	PROPIONIC ACID
548.	METHYLACRYLALDEHYDE	METHYLACRYLALDEHYDE
549.	METHYLAL	METHYLAL
550.	METHYLAMINE	METHYLAMINE
551.	METHYLARSINE DICHLORIDE	METHYL DICHLOROARSINE
552.	METHYLBENZENE	TOLUENE
553.	METHYLBENZOL	TOLUENE
554.	METHYL CHLORIDE	METHYL CHLORIDE
555.	METHYL CHLOROFORM	1,1,1-TRICHLOROETHANE
556.	METHYL CYANIDE	ACETONITRILE
557.	METHYLDICHLOROARSINE	METHYLDICHLOROARSINE
558.	METHYLENE ACETONE	METHYL VINYL KETONE
559.	METHYLENE CHLORIDE	DICHLOROMETHANE
560.	METHYLENE DICHLORIDE	DICHLOROMETHANE
561.	METHYLENE DIMETHYL ETHER	METHYLAL
562.	METHYLENE OXIDE	FORMALDEHYDE
563.	METHYL OXIRANE	PROPYLENE OXIDE
564.	METHYLEHTYLENEIMINE	PROPYLENEIMINE
565.	METHYLETHYLMETHANE	BUTANE
566.	METHYLHYDRAZINE	METHYLHYDRAZINE
567.	METHYLMETHANAMINE	DIMETHYLAMINE
568.	METHYLPHENOLS	CRESOLS
569.	METHYLPROPANOIC ACID	ISOBUTYRIC ACID
570.	METHYLPROPIONIC ACID	ISOBUTYRIL ACID
571.	MEVINPHOS	MEVINPHOS

INDEX	SYNONYM	CHEMICAL NAME
572.	MIC	METHYL ISOCYANATE
573.	MIXTURE OF BENZENE, TOLUENE AND XYLENES	NAPTHTHA (COAL TAR)
574.	MMH	METHYLHYDRAZINE
575.	MONDUR TDS	TOLUENE-2,4-DIISOCYANATE
576.	MONOALLYLAMINE	ALLYLAMINE
577.	MONOBROMOETHANE	ETHYL BROMIDE
578.	MONOCHLOROACETALDEHYDE	CHLOROACETALDEHYDE
579.	MONOCHLORODIFLUOROMETHANE	CHLORODIFLUORMETHANE
580.	MONOCHRLOROTRIMETHYLSILICON	MONOCHLOROTRIMETHYLSILICON
581.	MONOETHANOLAMINE	MONOETHANOLAMINE
582.	MONOETHYLAMINE	ETHYLAMINE
583.	MONOMETHYLAMINE	METHYLAMINE
584.	MONOMETHYLHYDRAZINE	METHYLHYDRAZINE
585.	MONOSILANE	SILANE
586.	MORPHOLINE	MORPHOLINE
587.	MPK	METHYL PROPYL KETONE
588.	MURIATIC ACID	HYDROCHLORIC ACID
589.	NACCONATE 100	TOLUENE-2,4-DIISOCYANATE
590.	NAPHTHA (COAL TAR)	NAPHTHA (COAL TAR)
591.	NAPHTHALENE	NAPHTHALENE
592.	NAPHTHALINE	NAPHTHALENE
593.	NICKEL CARBONYL	NICKEL CARBONYL
594.	NICKEL TETRACARBONYL	NICKEL CARBONYL
595.	NITRIC ACID	NITRIC ACID
596.	NITRIC ETHER	NITRIC ETHER
597.	NITRIC OXIDE	NITRIC OXIDE
598.	NITRITO	NITROGEN DIOXIDE
599.	NITROCARBOL	NITROMETHANE
600.	NITROCHLOROFORM	CHLOROPICRINE
601.	NITROETHANE	NITROETHANE
602.	NITROGEN DIOXIDE	NITROGEN DIOXIDE
603.	NITROGEN MONOXIDE	NITRIC OXIDE
604.	NITROGEN PEROXIDE	NITROGEN DIOXIDE
605.	NITROGEN TETROXIDE	NITROGEN DIOXIDE
606.	NITROGEN TRIFLUORIDE	NITROGEN TRIFLUORIDE

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607.	NITROMETHANE	NITROMETHANE
608.	NITROPROPANE	NITROPROPANE
609.	NITROTRICHLOROMETHANE	CHLOROPICRINE
610.	NITROUS ACID METHYL ESTER	METHYL NITRATE
611.	NONANE	NONANE
612.	OCTAFLUOROBUT-2-ENE	OCTAFLUOROBUT-2-ENE
613.	OIL OF VITRIOL	SULPHURIC ACID
614.	ORTHOARSENIC ACID	ARSENIC ACID
615.	ORVINYLCARBINOL	ALLYLALCOHOL
616.	OXALONITRILE	CYANOGEN
617.	2-OXOHEXAMETHYLENIMINE	CAPROLACTAM
618.	ORTHOPHOSPHORIC ACID	PHOSPHORIC ACID
619.	OXALIC ACID	OXALIC ACID
620.	OXIRANE	ETHYLENE OXIDE
621.	OXYDE DE CARBONE	CARBON MONOXIDE
622.	OXYTOLUENES	CRESOLS
623.	PARADI	p-DICHLOROBENZENE
624.	PARACHLOROBENZENE	p-DICHLOROBENZENE
625.	PARADOW	p-DICHLOROBENZENE
626.	PARAFORM	PARAFORMALDEHYDE
627.	PARAFORMALDEHYDE	PARAFORMALDEHYDE
628.	PCB	POLYCHLORINATED BIPHENYL
629.	PCL	HEXACHLOROCYCLOPENTADIENE
630.	PCM	PERCHLOROMETHYLMERCAPTAN
631.	PCP	PENTACHLOROPHENOL
632.	PENTA	PENTACHLOROPHENOL
633.	PENTABORANE	PENTABORANE
634.	PENTABORON NONAHYDRIDE	PENTABORANE
635.	PENTACARBONYLIRON	IRON PENTACARBONYL
636.	PENTACHLOROETHANE	PENTACHLOROETHANE
637.	PENTACHLOROPHENOL	PENTACHLOROPHENOL
638.	PENTAFLUORIDE	ANTIMONY PENTAFLUORIDE
639.	PENTAFLUROROANTIMONY	ANTIMONY PENTAFLUORIDE
640.	PENTALIN	PENTACHLOROETHANE
641.	PENTANAL	VALERALDEHYDE
642.	PENTANE	PENTANE

INDEX	SYNONYM	CHEMICAL NAME
643.	1-PENTANOL	n-AMYL ALCOHOL
644.	PENTYL ALCOHOL	n-AMYL ALCOHOL
645.	PERCHLOROBUTADIENE	HEXACHLOROBUTADIENE
646.	PERCHLOROCYCLOPENTADIENE	HEXACHLOROCYCLOPENTADIENE
647.	PERCHLOROETHYLENE	PERCHLOROETHYLENE
648.	PERCHLOROMETHYLMERCAPTAN	PERCHLOROMETHYLMERCAPTAN
649.	PERCLENE	PERCHLOROETHYLENE
650.	PERFLUORO-2-BUTENE	OCTAFLUOROBUT-2-ENE
651.	PERFLUOROETHENE	TETRAFLUOROETHENE
652.	PERFLUOROETHYLENE	TETRAFLUOROETHENE
653.	PERFLUOROPROPENE	HEXAFLUOROPROPYLENE
654.	PERFLUOROPROPYLENE	HEXAFLUOROPROPYLENE
655.	PEROXIDE	HYDROGEN PEROXIDE
656.	PHENOL	PHENOL
657.	PHENOXY PESTICIDES	2,4-DICHLOROPHENOXYACETIC ACID
658.	PHENYL CARBONIMIDE	PHENYL ISOCYANATE
659.	PHENYL ISOCYANATE	PHENYL ISOCYANATE
660.	PHENYLCARBIMIDE	PHENYL ISOCYANATE
661.	PHENYLMERCAPTAN	PHENYLMERCAPTAN
662.	PHOSDRIN	MEVINPHOS
663.	PHOSGENE	PHOSGENE
664.	PHOSPHINE	PHOSPHINE
665.	PHOSPHORIC ACID TRIETHYLENEIMIDE	TRI-(1-AZIRIDINYL)PHOSPHINE OXIDE
666.	PHOSPHORIC ACID TRIETHYLENEIMINE	TRI-(1-AZIRIDINYL)PHOSPHINE OXIDE
667.	PHOSPHORUS CHLORIDE	PHOSPHORUS CHLORIDE
668.	PHOSPHORUS OXYCHLORIDE	PHOSPHORUS OXYCHLORIDE
669.	PHOSPHORUS TRICHLORIDE	PHOSPHORUS TRICHLORIDE
670.	PHENYLAMINE	ANILINE
671.	n-PHENYLANILINE	DIPHENYLAMINE
672.	PHENYLETHANE	ETHYLBENZENE
673.	PHENYLMETHANE	TOLUENE
674.	PHOSPHORIC ACID	PHOSPHORIC ACID
675.	PHOSPHORUS	PHOSPHORUS
676.	PHOSPHORUS WHITE	PHOSPHORUS

INDEX	SYNONYM	CHEMICAL NAME
677.	POLYCHLORINATED BIPHENYL	POLYCHLORINATED BIPHENYL
678.	POLYCHLOROCAMPHENE	TOXAPHENE
679.	POLYFORMALDEHYDE	PARAFORMALDEHYDE
680.	POLYOXYMETHYLENE	PARAFORMALDEHYDE
681.	PROPALDEHYDE	PROPIONALDEHYDE
682.	PROPANAL	PROPIONALDEHYDE
683.	PROPANAMINE	PROPYLAMINE
684.	PROPANEITRILE	PROPIONITRILE
685.	1-PROPANOL	n-PROPYL ALCOHOL
686.	PROPARGYL ALCOHOL	PROPARGYL ALCOHOL
687.	PROPENAL	ACROLEIN
688.	PROPENAMIDE 50%	ACRYLAMIDE
689.	PROPENE-3-OL	ALLYL ALCOHOL
690.	2-PROPENENITRILE	ACRYLONITRILE
691.	PROPENOL	ALLYL ALCOHOL
692.	PROPENYL ALCOHOL	ALLYL ALCOHOL
693.	PROPENYLAMINE	ALLYLAMINE
694.	PROPIONALDEHYDE	PROPIONALDEHYDE
695.	PROPIONE	DIETHYL KETONE
696.	PROPIONIC ACID	PROPIONIC ACID
697.	PROPIONIC ALDEHYDE	PROPIONALDEHYDE
698.	PROPIONIC NITRILE	PROPIONITRILE
699.	PROPIONITRILE	PROPIONITRILE
700.	PROPYL ALCOHOL	n-PROPYL ALCOHOL
701.	n-PROPYL ALCOHOL	n-PROPYL ALCOHOL
702.	PROPYL ALDEHYDE	PROPIONALDEHYDE
703.	PROPYL CHLOROCARBONATE	PROPYL CHLOROFORMATE
704.	PROPYLCHLOROFORMATE	PROPYL CHLOROFORMATE
705.	PROPYL CYANIDE	BUTYRONITRILE
706.	PROPYL ISOCYANATE	PROPYL ISOCYANATE
707.	PROPYL NITRATE	PROPYLNITRATE
708.	PROPYLAMINE	PROPYLAMINE
709.	PROPYLENE ALDEHYDE	CROTONALDEHYDE
710.	PROPYLENE CHLOROHYDRIN	PROPYLENE CHLOROHYDRIN
711.	PROPYLENE DICHLORIDE	PROPYLENE DICHLORIDE
712.	PROPYLENE OXIDE	PROPYLENE OXIDE

INDEX	SYNONYM	CHEMICAL NAME
713.	PROPYLENEIMINE	PROPYLENEIMINE
714.	PROPYLIC ALDEHYDE	PROPIONALDEHYDE
715.	PROPYLNITRILE	PROPIONITRILE
716.	PRUSSIC ACID	HYDROGEN CYANIDE
717.	PYRROLYLENE	BUTADIENE
718.	QUICKLIME	CALCIUM OXIDE
719.	SANTOPHEN 20	PENTACHLOROPHENOL
720.	SEC-PROPYL ACETATE	ISOPROPYL ACETATE
721.	SELANE	HYDROGEN SELENIDE
722.	SELENINYL CHLORIDE	SELENIUM OXYCHLORIDE
723.	SELENIUM ANHYDRIDE	HYDROGEN SELENIDE
724.	SELENIUM CHLORIDE OXIDE	SELENIUM OXYCHLORIDE
725.	SELENIUM FLUORIDE	SELENIUM HEXAFLUORIDE
726.	SELENIUM HEXAFLUORIDE	SELENIUM HEXAFLUORIDE
727.	SELENIUM HYDRIDE	HYDROGEN SELENIDE
728.	SELENIUM OXYCHLORIDE	SELENIUM OXYCHLORIDE
729.	SILANE	SILANE
730.	SILICON FLUROIDE	SILICON TETRAFLUORIDE
731.	SILICON TETRAFLUROIDE	SILICON TETRAFLUROIDE
732.	SILICON TETRAHYDRIDE	SILANE
733.	SKELLYSOLVE B	HEXANE
734.	SODIUM CYANIDE	SODIUM CYANIDE
735.	STIBINE	STIBINE
736.	STROBANE T	TOXAPHENE
737.	SULPHUR CHLORIDE	SULPHUR MONOCHLORIDE
738.	SULPHUR DIOXIDE	SULPHUR DIOXIDE
739.	SULPHUR FLUORIDE	SULPHUR HEXAFLUORIDE
740.	SULPHUR FLUORIDE	SULPHUR TETRAFLUORIDE
741.	SULPHUR HEXAFLUORIDE	SULPHUR HEXAFLUORIDE
742.	SULPHUR TETRAFLUORIDE	SULPHUR TETRAFLUORIDE
743.	SULPHURETTED HYDROGEN	HYDROGEN SULPHIDE
744.	SULPHURIC ACID	SULPHURIC ACID
745.	SULPHURIC ACID SPENT	SULPHURIC ACID
746.	SULPHURIC CHLOROHYDRIN	CHLOROSULPHURIC ACID
747.	SULPHUR MONOCHLORIDE	SULPHUR MONOCHLORIDE
748.	SULPHUR SUBCHLORIDE	SULPHUR MONOCHLORIDE

INDEX	SYNONYM	CHEMICAL NAME
749.	SULPHURIC OXYFLUORIDE	SULPHURYL FLUORIDE
750.	SULPHURYL FLUORIDE	SULPHURYL FLUORIDE
751.	SUPEROXOL	HYDROGEN PEROXIDE
752.	TAR CAMPHOR	NAPHTHALENE
753.	TDI	TOLUENE-2,4-DIISOCYANATE
754.	TEL	TETRAETHYL LEAD
755.	TELLURIUM FLUORIDE	TELLURIUM HEXAFLUORIDE
756.	TELLURIUM HEXAFLUORIDE	TELLURIUM HEXAFLUORIDE
757.	TETRA ALKYL LEAD	TETRAETHYL LEAD
758.	TETRABROMOETHANE	TETRABROMOETHANE
759.	TETRACAP	PERCHLOROETHYLENE
760.	TETRACARBONYL NICKEL	NICKEL CARBONYL
761.	TETRACHLOROETHANE	TETRACHLOROETHANE
762.	TETRACHLOROETHYLENE	PERCHLOROETHYLENE
763.	TETRACHLOROMETHANE	CARBON TETRACHLORIDE
764.	TETRAETHYL LEAD	TETRAETHYL LEAD
765.	TETRAFLUOROETHENE	TETRAFLUOROETHENE
766.	TETRAFLUOROETHYLENE	TETRAFLUOROETHENE
767.	TETRAFLUOROSULPHURANE	SULFUR TETRAFLUORIDE
768.	TETRAHYDRO-1,4-DIOXIN	DIOXANE
769.	TETRAHYDRO-p-OXAZINE	MORPHOLINE
770.	TETRAHYDRO-2H-1,4-OXAZINE	MORPHOLINE
771.	TETRAMETHYL LEAD	TETRAMETHYL LEAD
772.	THIOBUTYL ALCOHOL	BUTYL MERCAPTAN
773.	THIOCARBONYL CHLORIDE	THIOPHOSGENE
774.	THIOCARBONYL TETRACHLORIDE	PERCHLOROMETHYL MERCAPTAN
775.	THIOETHANOL	ETHYL MERCAPTAN
776.	THIOETHYL ALCOHOL	ETHYL MERCAPTAN
777.	THIOETHYL ETHER	DIETHYL SULFIDE
778.	THIOGLYCOL	THIOGLYCOL
779.	THIOMETHANOL	METHYL MERCAPTAN
780.	THIOMETHYL ALCOHOL	METHYL MERCAPTAN
781.	THIOPHENOL	PHENYL MERCAPTAN
782.	THIOPHOSGENE	THIOPHOSGENE
783.	TITANIC CHLORIDE	TITANIUM TETRACHLORIDE
784.	TITANIUM TETRACHLORIDE	TITANIUM TETRACHLORIDE

INDEX	SYNONYM	CHEMICAL NAME
785.	TMA	TRIMETHYL AMINE
786.	TML	TETRAMETHYL LEAD
787.	TOLUENE	TOLUENE
788.	2,4-TOLUENE DIISOCYANATE	TOLUENE-2,4-DIISOCYANATE
789.	TOLUENE-2,4-DIISOCYANATE	TOLUENE-2,4-DIISOCYANATE
790.	TOLUIDINE	TOLUIDINE
791.	TOLUOL	TOLUENE
792.	TOLYL CHLORIDE	BENZYL CHLORIDE
793.	TOPANEL	CROTONALDEHYDE
794.	TOXAPHENE	TOXAPHENE
795.	TOXILIC ANHYDRIDE	MALEIC ANHYDRIDE
796.	TRI-(1-AZIRIDINYL)PHOSPHINE OXIDE	TRI-(1-AZIRIDINYL)PHOSPHINE OXIDE
797.	TRIBROMOETHANE	BROMOFORM
798.	TRICHOLORBORANE	BORON TRICHLORIDE
799.	TRICHLOROBORON	BORON TRICHLORIDE
800.	1,1,1-TRICHLOROETHANE	1,1,1-TRICHLOROETHANE
801.	TRICHLOROETHANE	1,1,1-TRICHLOROETHANE
802.	TRICHLOROETHENE	TRICHLOROETHYLENE
803.	TRICHLOROETHYLENE	TRICHLOROETHYLENE
804.	TRICHLOROETHYLSILANE	ETHYL TRICHLOROSILANE
805.	TRICHLOROETHYLSILICANE	ETHYL TRICHLOROSILANE
806.	TRICHLOROMETHANE	CHLOROFORM
807.	TRICHLOROMETHANESULPHENYL CHLORIDE	PERCHLOROMETHYLMERCAPTAN
808.	TRICHLORONITROMETHANE	CHLOROPICRINE
809.	TRICHLOROPHOSPHINE	PHOSPHORUS TRICHLORIDE
810.	TRICHLOROPHOSPHINE OXIDE	PHOSPHORUS OXYCHLORIDE
811.	TRICHLOROPHOSPHORUS OXIDE	PHOSPHORUS OXYCHLORIDE
812.	TRICLENE	TRICHLOROETHYLENE
813.	TRIFLUOROBORON	BORONTRIFLUORIDE
814.	TRIISOPROPYL BORATE	TRIISOPROPYL BORATE
815.	TRIMETHOXYPHOSPHINE	TRIMETHYLPHOSPHITE
816.	2,4,4-TRIMETHYL-1-PENTENE	DIISOBUTYLENE
817.	TRIMETHYLAMINE	TRIMETHYLAMINE

INDEX	SYNONYM	CHEMICAL NAME
818.	TRIMETHYLCHLOROSILANE	TRIMETHYLCHLOROSILANE
819.	TRIMETHYLPHOSPHITE	TRIMETHYLPHOSPHITE
820.	TRIMETHYLSILY CHLORIDE	TRIMETHYLSILY CHLORIDE
821.	TRIOXYMETHYLENE	PARAFORMALDEHYDE
822.	TRIPROPYLAMINE	TRIPROPYLAMINE
823.	TROPILIDENE	CYCLOHEPTATRIENE
824.	UDMH	DIMETHYL HYDRAZINE
825.	UNSLAKED LIME	CALCIUM OXIDE
826.	VALERAL	VALERALDEHYDE
827.	VALERALDEHYDE	VALERALDEHYDE
828.	VALERIC ALDEHYDE	VALERALDEHYDE
829.	VAM	VINYL ACETATE
830.	VANADIC ANHYDRIDE	VANADIUM PENTOXIDE
831.	VANADIUM PENTAOXIDE	VANADIUM PENTOXIDE
832.	VANADIUM PENTOXIDE	VANADIUM PENTOXIDE
833.	VCL	VINYL CHLORIDE
834.	VCM	VINYL CHLORIDE
835.	VINEGAR ACID	ACETIC ACID
836.	VINEGAR NAPHTHA	ETHYL ACETATE
837.	VINYL ACETATE	VINYL ACETATE
838.	VINYL A MONOMER	VINYL ACETATE
839.	VINYL BROMIDE	VINYL BROMIDE
840.	VINYL CHLORIDE	VINYL CHLORIDE
841.	VINYL C MONOMER	VINYL CHLORIDE
842.	VINYL CYANIDE	ACRYLONITRILE
843.	VINYL FLUORIDE	VINYL FLUORIDE
844.	VINYL METHYL ETHER	VINYL METHYL ETHER
845.	VINYLCARBINOL	ALLYAL ALCOHOL
846.	VINYLETHYLENE	BUTADIENE
847.	VINYLIDENE CHLORIDE	VINYLIDENE CHLORIDE
848.	VINYLIDENE DICHLORIDE	VINYLIDENE CHLORIDE
849.	VINYLIDINE CHLORIDE	VINYLIDENE CHLORIDE
850.	VYAC	VINYL ACETATE
851.	WHITE CYANIDE	SODIUM CYANIDE
852.	WHITE PHOSPHORUS	PHOSPHORUS
853.	WOOD ETHER	DIMETHYL ETHER

INDEX	SYNONYM	CHEMICAL NAME
854.	XYLENES	XYLENES
855.	XYLOLS	XYLENES
856.	YELLOW PHOSPHORUS	PHOSPHORUS

II. FIRE HAZARD CODE

1. Flammable.
2. Not flammable.
3. Combustible.
4. Vapour may explode if ignited in an enclosed area.
5. Irritating vapours generated.
6. Poisonous and toxic vapours are produced when heated.
7. Flashback along vapour trail may occur.
8. Vapour is heavier than the air.
9. Toxic oxides of nitrogen may form in fire.
10. Highly flammable liquid.
11. Poisonous gases (Hydrogen Cyanide and Nitrogen Oxides).
12. Presence of oil or other combustible materials increases fire hazard.
13. Emits toxic fumes when heated.
14. Emits toxic fumes on decomposition.
15. Irritating gases generated in fire.
16. Toxic and irritating gases are produced in fire.
17. Containers may explode in fire.
18. Can react with oxidizing material.
19. May cause fire on contact with water and combustibles.
20. Decomposes to carbon monoxide and hydrogen cyanide in fire.
21. Toxic gases are generated.
22. Poisonous and irritating phosgene, chloride and hydrogen chloride gases are produced in fire.
23. May ignite on contact with air.
24. Flammable toxic vapours and poisonous gases are generated in fire.
25. Vapour forms explosive mixture with air.
26. Emits highly toxic fumes when heated to decomposition.
27. Toxic and irritating phosgene gas produced in fire.
28. If mixed with air in critical proportions and in presence of a source of fire, it ignites.
29. Reacts vigorously with metals such as aluminum and magnesium.
30. Toxic and irritating hydrogen chloride and phosgene gases are produced in fire.

31. Irritating vapours are produced when heated.
32. Toxic vapours are generated.
33. Toxic vapours are generated in fire.
34. Flammable gas may be produced on contact with metal.
35. Toxic and irritating chloride vapour produced when heated.
36. Toxic and irritating fluoride vapour produced when heated.
37. Flammable and explosive hydrogen gas produced on contact with metals.
38. Pressurized container explodes and releases toxic and irritating vapours.
39. Causes fire and explodes on contact with combustibles and metals.
40. Toxic oxides of sulphur produced in fire.
41. Dust cloud may be ignited by spark or flames, generating heat and toxic fumes.
42. Toxic and irritating fumes of nitrogen oxides produced when heated.
43. Black smoke, toxic fumes and gases including oxides of carbon and nitrogen are produced when burning in air.
44. Releases flammable and toxic formaldehyde vapours.
45. When heated, forms formaldehyde gas and oxides of carbon.
46. Poisonous gases produced in fire.
47. Poisonous and irritating gases of oxides of phosphorous are produced in fire - forms intense white smoke.
48. Releases highly hazardous cyanides when heated to decomposition or on contact with acid or acid fumes.
49. Container may rupture and release toxic and irritating sulphur dioxide.
50. Toxic and corrosive fumes of chloride and sulphur oxide are produced when heated.
51. Highly toxic fumes of lead produced in fire.
52. Reacts vigorously with oxidizing material.
53. Will increase intensity of fire when in contact with combustibles.
54. Toxic gases of hydrogen chloride, phosgene and carbon monoxide produced in fire.

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